GERMINATION

IN

ITS ELECTRICAL ASPECT

A CONSECUTIVE ACCOUNT OF THE ELECTRO-PHYSIOLOGICAL PROCESSES CONCERNED IN EVOLUTION, FROM THE FORMATION OF THE POLLEN-GRAIN, TO THE COMPLETED STRUCTURE OF THE SEEDLING

TOGETHER WITH

SOME FURTHER STUDIES IN ELECTRO-PHYSIOLOGY

BY

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WITH OVER 130 DRAWINGS FROM ORIGINAL PHOTOGRAPHS

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This Work is Dedicated to the Educated Men and Women of the World, in the hope and belief that some of them, free from the shackles of scientific jealousy and unhampered by medical "ethics," will come forward and assist in the dissemination of a Great Truth.

PREFACE

WHEN this book, a plainly written account of laborious research, passes into the hands of reviewers I would ask those gentlemen to remember that a great humanitarian question is involved and that while my personal opinion upon matters of detail may seem worthy of attack, the fundamental truth I have put forward, first in *Electro-Pathology and Therapeutics*, second in *Studies in Electro-Physiology* and for the third time in the present volume is of too great importance to mankind to be passed over, or to be, to all intents and purposes, shelved, by saying there is very little that is new in it.

One outcome of my research work has been Dielectric Therapy, the use of a standardised paraffin in the treatment of local pyrexia. There is abundant evidence to prove that by the use of this remedial agent pneumonia can be deprived of its danger in a few hours, that it removes all pain from burns in a few seconds and that as it does not interfere with metabolism it promises to displace the antiseptic method of treatment of wounds. If that is not new why, I ask, is there no mention of paraffin as a remedy for local pyrexia in the *Pharmacopœia?* Many hundreds of physicians have had experience of its efficacy.

What I have endeavoured to do is to study natural processes and to find out exactly what happens and how it happens, and I hit upon a line of research which has been productive of enlightenment. It has enabled me to explain many things that were lacking of explanation and to view physiological problems from a new standpoint; to peer through the door opening into a hitherto unexplored field and to describe such things as I have been able to see.

It is not fair play to suggest that my work has, in any way, in any degree, been anticipated by Burdon-Sanderson's studies of a leaf of Venus's fly-trap, or by the academic labours of Professor Bose, because it is not true. Nor is it understandable why if physiologists are capable and experienced electricians they fail to tell us anything about the human electrical system.

The issue is a plain one : I am either right or I am wrong. If I am right then a brighter prospect opens for humanity. If I am wrong—and it would be a very extraordinary thing to find so long a chain of coincidences—it is easy enough to prove me to be so by giving another and more intelligible explanation of vital phenomena. In the meantime there is no explanation, other than that for which I am responsible; although Dr. Geo. W. Crile and, I have no doubt, other able men are close upon the heels of the truth.

In the present work I have attempted, and I think it is the first time it has been attempted, to give a consecutive account of the electro-physiological processes concerned in evolution, from the formation of the pollen grain to the completion of the structure of the young plant. In regard to the other Studies in Electro-Physiology which help to swell the volume I would point out that the thesis upon the Auditory Apparatus opens up a, I submit, more detailed and reasonable theory of the operation of what has been called "the Mechanism of Hearing" than others which, in more senses than one, have gone before it.

A. E. BAINES.

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GERMINATION

INTRODUCTORY

I HAVE been trying, like many other and better men who have gone before me, to peer through the veil that hides from us the principle underlying what we call life. The difficulty has been, or at all events my difficulty has been to get back to the very commencement of some form of life in a process which is not only continuously reproductive, but which began ages before man came into being on the earth.

For a good many years I held the opinion that the only way to arrive at some understanding of the subject was to study plant life. The human fœtus, prior to birth, is dependent upon the maternal blood-stream and may be said to live, if only with the life of the mother, until it commences, with its first breath, an independent existence. But it *lives*, in the sense that it is not dead, nor in a state of suspended animation. That before birth circulation is not completed through its lungs and it is not able to do the things of which the infant is capable, does not affect the question. It is alive.

In the plant much the same thing obtains. The children of the plant are its seeds and if we consider the process of sexual reproduction we shall see that no hard and fast line of separation can be drawn between animal and vegetable.

In his *Text Book of Biology*, Davis, writing of gymnosperms, cites the Selaginella, a common greenhouse plant, as an illustration of sexual reproduction.

In this the sporophyte bears male and female spores—Microspores and Macrospores. Within the Microspore is developed a very rudimentary male prothallus, which originates one or more antheridia, producing mobile spermatozoids. Within the Macrospore a rather larger female

prothallus is formed, in which one or more archegonia arise. These are exposed to the exterior by the bursting of the coats of the macrospore, and are fertilised by the spermatozoids in the usual way.

As the prothallus is, in effect, a genital organ, it follows that the process is essentially the same in both animal and plant. The main difference appears to be that with the first the act is a conscious one and in the second, so far as we know, unconscious.

Lord Avebury, in his work on *Seedlings*, says: "The seed is the result of the fertilisation of the ovule by the pollen. The effect of fertilisation, however, extends in the angiosperms beyond the ovules to the ovary in which they are contained. The ovary thus becomes the fruit, as the ovule has become the seed. In the apple, for instance, the edible portion consists of the greatly developed floral receptacle, which includes the ovary as its core. The ovules are borne usually on some definite part of the ovary wall or walls, known as the placenta. They consist of an internal portion, the nucellus, one cell of which grows at the expense of the rest to form an embryo-sac, which again contains the egg-cell or oosphere, and one or two integuments entirely surrounding the nucellus, except at the apex where a small aperture, known as the micropyle, is left. In the process of fertilisation the pollentube passes down the micropyle to the oosphere, which, enclosed in the embryo-sac, approaches very close to the outer wall of the ovule at this point. After fertilisation the oosphere developes into the embryo, the rest of the embryo-sac becoming filled with a cellular tissue, the endosperm."

That, I think, is sufficiently descriptive of the principle involved but there is, as may be imagined, considerable variety in the position and arrangement of the ovule and subsequently of the seed.

And here is a point I should like to make.

Strasburger remarks that it is the *non-motile* egg-cells, or female sexual organs of plants which exert an attractive influence upon the motile male cells, but adds that when there is no difference in the external form of the male and

female cells, then both are usually motile and the attraction seems to be exerted mutually.

From this it would appear to be evident that the male and female cells are in any case of opposite polarity and that when the female organ is non-motile it is because its electrical tension is greatly in excess of that of the male cell.

Another analogy between animal and vegetable is to be found in the placenta which although common enough is perhaps best exemplified in the runner bean. In the human being the placenta is a spongy, vascular mass through which the maternal blood is conveyed to the fœtus and which also secretes glycogen, possibly for the purpose of sustaining animal heat. In the plant it is a projection on the inner wall of the ovary, to which the ovules, or rudimentary seeds, are attached.

As regards the inception of the seed we cannot go further back in its history than the formation of the pollen-mother and as vital processes are continually going on, there is life—although it may be only the life of the mother plant—and we are no nearer to a perception of the origin of life than we were with the animal embryo.

But several considerations present themselves.

In the first place cell-division in both animal and vegetable is electrical in character, as I shall show. Secondly, What is it that enables the newly-born child to begin a life that is independent of the mother? It is the act of breathing. Only at birth is circulation completed through the lungs. Before they were required to take in oxygen, to sustain life and render the young body independent of the mother, there was no need for its blood to circulate *through the lungs* for that would have meant separate life before birth and would be as unusual if not as unnatural as the germination of a seed while still attached to the parent plant, although an instance of this has been noted by Strasburger; the seed of mangrove trees, *Rhizophora* and *Bruguiera* germinating in the fruit before it is detached from the tree. When the radicle has attained a considerable length, the young seedling, separating either from the cotyledons or from the

fruit stalk, falls and bores into the mud. There is also an analogue, in vegetative reproduction, in the sporophytic budding of the *Asplenium Fabianum ; A Bulbiform* and *A Viviparum*, all of which produce buds on their laminæ. These develop into small rooted plants, which then fall off and complete their development. Adventitious budding is fairly common in vegetative reproduction but I have not heard of an instance, other than that mentioned, of adventitious germination in sexual reproduction. This, however, is digression.

In the act of breathing, oxygen is brought into association with hæmoglobin and the force which actuates the human organism is generated. The heart continues to beat, driven by the infant's own power, the blood carries energy as well as oxygen in the arterial stream to every cell in the body and the processes of anabolism and katabolism proceed.

And this gives fresh food for thought. The atmosphere is admittedly positive, as the earth is negative. By what is the air positively charged ? We must, I think, assume, in the absence of any other explanation, that it is by energy from some supermundane source. And if it is so charged do we—and I include the plant—inspire oxygen and nitrogen —plus some other gases—only, or is that oxygen and nitrogen mixture charged with the same form of energy ? Is it air, or vitalised air ?

I do not see how it can be otherwise than vitalised, if vitality and energy are in any way related. Nor is that all. Are we not to take into consideration, if not into account, the possible evolution of energy from light-frequencies ?

I do not know of any method of measuring the energy exerted by, for instance, sunlight, until it is transformed into heat. But that it is a force in motion is unquestionable. Sunstroke cannot be produced by artificial means. Heat alone does not originate the symptoms which, however, closely resemble those due to concussion of the air and are known as "shell-shock." They are probably caused by light-vibration—possibly by ultra-violet rays—but while

that is speculative, I am fortunately able to support the hypothesis that light is a force in motion by proof.

An onion in good condition will when tested galvanometrically, if the instrument is a sensitive one, give a large deflection; its electromotive force being 0.086 volt. If the vegetable is "earthed" in vacuo that deflection will, after some thirty or forty minutes, fall to zero, because the source of charge, the air, has been cut off; and thereafter no deflection other than one due to a vagrant earth-current will be observed. If now the onion is removed from the apparatus and exposed to the air in a room in a dull subdued light it will not recover sufficiently to yield its initial deflection for several days. In the open air, in the sun, it recovers in an hour or so or less.

That, I submit, goes to show that a very real force is exerted by sunlight and this view is supported by Professor Bose.

From these considerations one is led irresistibly to the experiments of that distinguished surgeon, Dr. Alexis Carrel, experiments which have been responsible for the theory that life is merely a product of chemical reaction. That is a statement made by Dr. Jacques Loeb, Dr. Carrel's colleague at the Rockefeller Laboratories. Professor Schäfer is also reported to have declared that there is not a great difference, after all, between dead and living matter.

I propose to subject both those statements to the test of common sense, backed by ascertained fact.

Dr. Carrel extirpated from his experimental animals—I am taking an account from *The World's Work*, of March, 1913—a chicken, a dog, a cat, or a frog—pieces of tissue. He selected small samples of the most important bodily organs—pieces of skin, of liver, of heart, of kidney, of spleen, of thyroid gland, of bone and cartilage. Placing these specimens upon a microscopic slide, he poured upon each a drop or two of blood plasma.

The glass slides containing the specimens were then placed in an incubator, heated up to the body temperature—and the specimens *grew*.

The experiments themselves are full of interest, reflect

great credit upon the brilliant young scientist who made them and constitute a valuable addition to our knowledge, but—*there is nothing whatever in them to justify the conclusion that life is merely a product of chemical reaction.*

In the first place, every animal, and vegetable, cell is a self-contained piece of electrical apparatus, the chemical processes of which are dependent upon its response to body energy, *vis nervosa*, neuro-electricity ; call it what you will.

Secondly, everything that is moist possesses capacity and also true electrostatic capacity, though in the latter case power to retain charge is directly with its absolute insulation. By capacity I mean the ability to absorb electrical charge from some outside source of energy, and in this case the outside source is the atmosphere. There is no reason that I can see why, given a measure of natural energy, excised cells should *not* grow.

Even without the energy of which I have made mention growth should continue at body temperature in the presence of blood plasma because iron is contained in the nucleo-proteins of plant and animal cells and in the proteins of blood plasma. Iron is fifth in the list of electro-positives and oxygen the most active of electro-negatives. The two, in combination with the salts of plasma as an exciting solution are capable of generating electricity, or some force akin to it, and so supplying the *vis nervosa.*

We cannot call this a chemical phenomenon. If it is an indication of *life*, then it is the *vis nervosa* that gives it. It is rather a manifestation of electrical energy than of chemical reaction and I am quite sure that if the iron content of the cells and of the plasma could be removed or, preferably, experiments tried in vacuo, no growth could possibly take place.

Moreover, that is not my conception of life. If Dr. Carrel had taken pieces of skin, of liver, of heart, of kidney, of spleen, of thyroid and other glands, of muscle and bone, and cartilage of, say, a chicken, placed them in an incubator and produced a hen capable of laying an egg, or a cock that could crow, we should have no option but to agree that he had done a very wonderful thing. Nevertheless, it would

not, any more than the other experiments, prove that life is the result of chemical reaction.

Upon the subject of Professor Schäfer's statement that there is not a great difference between dead and living matter, I have to say that there is this difference :—Supposing both to be structurally perfect one is dependent upon an outside and artificial source of energy while the other forms part of a continuously active natural circuit. Mere movement is not life, for the motions of the amœba can be imitated by means of oil and soap and water; growth does not necessarily postulate life, for the cancer-cell proliferates and disintegrates in so doing. If to live is to be natural the cancer-cell is never alive, for it is never perfectly formed. You may simulate life by exciting excised cells into action by artificial stimuli but they are just pieces of mechanism —nothing more. Life is exemplified by the perfected organism, if not sentient at least exercising to the full the functions for which it was created.

Dr. Waller, in his *Signs of Life*, examines the problem of the unplanted seed. He says: "Now dry seeds kept for long periods in hermetically sealed vessels, have not been found to manifest any evidence of the most fundamental and general chemical change occurring in living matter, *viz.*, a production of CO^2. Their chemical reply to the question, 'Are you alive?' has been 'No.'

"But does this negative answer, 'Not alive,' imply that such seeds are dead? Evidently not, as may be seen if under suitable conditions of temperature, moisture, and so forth, they are found to germinate, and grow into plants. So that a seed, in so far as it does not manifest chemical change, is not proved to be living; and, inasmuch as it germinates, is proved not to be dead. Evidently here is a dilemma; in the absence of an objective chemical sign of life, we have no right to say that a seed is alive; it is, so far as we can tell, not alive; in the presence of its subsequent germination we are assured that it is living and that therefore it was not dead. And the usual manner of escape from this dilemma of the seed which is neither living nor dead is to say that it is in a state of *latent life*, during which

there is a complete suspension of chemical changes characteristic of the living state."

That is an explanation but not I think, the true explanation. Dr. Waller goes on to say that by means of an electrical test he can tell whether a seed is alive or dead. I am sorry to be at issue with him, but he is mistaken. No electrical test will show anything of the sort. Reference to the Chapter upon "The Structure of the Seed" will make this clear. Nothing short of a microscopical examination showing degeneration—equivalent to putrefaction in the animal body—can determine the question of life or death in a *dry* seed, although its electrical fitness, or otherwise, could be determined by moistening the seed coat, charging it by means of continuous current for a few seconds and then discharging it through the galvanometer. But the fact that it gave a sensible deflection would no more prove it to be alive than it would show a Leyden jar or a condenser to be alive. And I say that the seed is not in a state of *latent* but of *potential* life.

Let us consider the matter from a common sense point of view.

The animal fœtus is constructed to commence an independent existence *the moment the umbilical cord is severed.* Unless it then inspires oxygen and generates force to call its body functions into instant operation it dies, for it has had no life of its own but only the life of the mother. Not so, however, with the seed. Just before the animal draws its first breath and when the grown seed falls from the parent plant both are structurally perfect, but what the first breath is to the animal so is the natural environment of soil and warmth and moisture to the seed, and it is obviously not intended that it should perish if that environment was not immediately forthcoming. The seed, in my belief, is just a piece of apparatus to which life can be imparted when the conditions essential to its completion are complied with, and not before.

It is almost as if we were considering it as the recording instrument in a telegraphic circuit. Everything is in order, the battery, the keys, the condensers, the line wire, the

earth connections and the instrument. But the latter is silent and would for ever so remain did not some agency depress the key connecting up the battery and so enable the vitalising current to traverse its coils. The main difference between the instrument and the seed is that the stimulus applied to the seed is continuous; to the other intermittent. Accident, such as a flash of lightning, might compel the armature of the instrument to temporary movement, and dampness and warmth, by rendering the seed-coat conductive, and so enabling it to absorb energy from the air, might stimulate the seed to life. But without energy of an electrical nature neither piece of apparatus can function.

In the studies in Electro-Physiology which follow I am going to assume that my readers are acquainted with all there is to be said upon the subject of botany and that they have embryology, so far as it is understood by anyone, at their finger's ends. It will not only save me a great deal of trouble, but what is, to me, of more importance, it will enable me to concentrate upon germination in its electrical aspect and to avoid many of the rocks and pitfalls of fearsome words and occasionally misleading theory. Botany should be a fascinating study to the young. It has been made a heart-breaking one, for the student has almost to master another language before he can become familiar with the structure of a single blossom. Embryology, which should hold more interest than any other branch of science, is, like physiology, wanting a link, and without that link, unsatisfying. We are told what happens, but not why or how it happens. Students are taught that all vital functions are due to chemical action and that kinetics play no part in the phenomena. And with what result? Take any work upon Physiology, and what do we find? The mechanism of hearing "further investigation of hearing is called for, the function of the Cochlea is imperfectly understood"; the eye: "We do not yet understand the phenomenon of vision," and so forth. Physiology deals with the chemical processes of the body and apart from them and histological description, explains nothing. We are not told what causes voluntary muscle to contract; what the force is

that supplies the heart with energy during every second of our lives: what actuates plain muscle, how we see pictures and hear sounds, or why we sleep.

As it is in animal so it is in vegetable physiology. Admirable work has, it is true, been done in Histology, Morphology and in Anatomy. Those deal with things that can be seen. The unseen remains for the most part—unseen.

And, unfortunately, the average man takes far less interest in his own body than in that of his favourite horse or dog. It is easy enough to understand the working of a steam or internal combustion engine, because we have been shown that one is driven by volatilised water and the other by volatilised petrol, or paraffin, or benzol, or gasoline, but while we all know that the human body is an organism of a much more wonderful nature than any engine invented by man, it is not supposed to be actuated by any motive power at all; or at all events, no one seems to know what the motive power is, although common sense tells us it must exist.

In the seed, in the plant, in the cell or cells from which all living things spring, the electrical structure is so clearly evident as to leave very little, if any, doubt as to the form of energy which calls them into activity, and maintains them and the chemical processes associated with them.

Some explanation of the chaotic state in which we find theories of life and action offers itself in the fact that for some obscure reason it is sought to establish a single cause of vital phenomena. It is chemical or it is electrical; one or the other—when, clearly, it is both. The theorist who, like myself, attributes the performance of body functions to a force resembling electricity cannot but admit that the chemical reactions which accompany those performances are equally vital in their importance to life; he merely postulates that neuro-electrical action is precedent to chemical change. The physiologist, however, in effect, denies the existence of a nerve-force of an electrical nature and insists upon chemistry as being responsible for all the phenomena which the chemical theory itself fails throughout to explain.

That, if I may venture to say so, is not a scientific attitude, nor one that, in view of the humanitarian question involved, should be tolerated. Whether a vital force is really generated in the animal body and in the plant and whether electrical interchanges take place between the atmosphere and the earth are problems that readily lend themselves to study and solution. Few difficulties are in the way. It involves merely a few weeks' or a few months' work on the part of qualified men—electricians as well as physiologists—and I hope that in the near future an investigation will be set on foot, for it is not a matter of testing a theory but of verifying a great truth.

CHAPTER I.

LIFE AND ELECTRICITY

IN the first place, let us ask the momentous question, "What is life?" The best answer I have seen is given by the *American Medical Dictionary* which defines it as "a peculiar stimulated condition of organised matter."

And if it is a stimulated condition of organised matter upon what is it dependent for its continuance? Not, as a whole, upon oxygen for we are confronted by the problem of anærobic micro-organisms which are said to live without it; not upon food or heat; against that we have hibernation, the imprisonment of toads for long periods of time in stone or wood, of survival in fact under conditions seemingly fatal to life. The dried seed if it does not live is possessed of potential life so long as its testa is kept dry and the liquid content of the seed-substance remains; while in the absence of electrical diffusion, consequent upon organic disintegration, suspended animation may simulate death so closely as to lead to premature burial.

Dr. Benjamin Ward's paper upon *Resuscitation after certain forms of symptomatic death* suggested that death is sometimes more apparent than real and I have a vivid recollection of his showing me, many years ago, how to resuscitate frozen fish.

Carpenter tells us that it is unquestionable that many fishes, especially those of fresh-water lakes, will revive after having been completely frozen; that the snail, when retiring for the winter, seals the orifice of its shell with an impervious lid; and in this cavity it may remain shut up for years, until re-excited to activity by warmth and moisture.

Dr. David Fraser Harris, writing in *Knowledge*, instances certain bacteria which after being frozen at the temperature of liquid air (about minus 200C.) were not killed, but

could survive so extremely drastic a procedure as this and yet retain their specific vital pathogenic characteristics. When frozen they were so brittle that they could be powdered in a mortar, they were nevertheless in a state of latent life. He concludes as follows :

"Thus, the solution of our problem, What is latent life? seems capable of being stated in the terms of the already known. The organism in latent life is not dead, for it is capable of living again ; it is, however, very far from being fully alive, for it is manifesting none of the attributes of livingness.

"Without a chemical theory of living matter 'suspended animation would be inexplicable.'"

With the last paragraph I certainly do not agree. The chemical theory does not explain suspended animation or help us to a clear understanding of life.

*"The death of the body then, does not consist in the mere suspension of its vital activity ; for so long as that activity may be renewed *when the requisite conditions are supplied,* so long must the organism be considered as alive, however death-like its condition may seem." The italics are mine.

No question can be more complex, but the two words "Warmth" and "Moisture" are full of significance. Warmth increases the conductivity of the nerves, and moisture gives capacity, or power of absorption of electrical energy from the air. From that we may gather a little light, but altogether must take the view that a force at present unrecognised in our schools operates in sustaining if not in creating what we call life.

Let us go back, if not to the very beginning of things, at all events as far as we can, to the reproduction of the cells of which all animal and vegetable bodies are built up, and see exactly what takes place.

I quote the following from *The Evolution of Sex,* by Geddes & Thomson.

"That attractions and repulsions do exist within the cells is certain ; an analysis of their precise nature—the

*Carpenter.

final problem of histology—is still far in the distance. We cannot get within miles of it."

The secret of the whole matter, the constant generation of nerve force within the animal organism, has hitherto not been discovered, or at least, admitted. I will endeavour to add to our knowledge of the subject.

In what is termed its "resting" stage, but really during development, the cell presents the following appearance :—

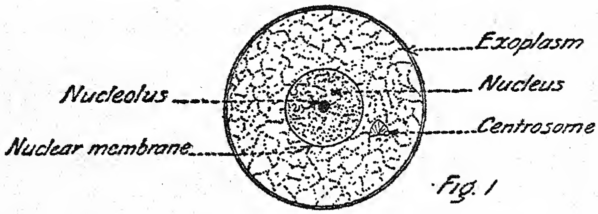


Fig. 1

Before entering upon explanation I must premise that the acuating force is not electricity as we understand it, but a cognate and, I believe, a more subtle and powerful force. As, however, we are not able to define its exact nature we will continue to call it electricity.

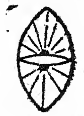
In the blood is an iron-containing substance known as hæmoglobin. Iron is fifth in the list of electro-positives. Oxygen is the most active of practicable electro-negatives. The oxygen intake of man, during the daytime, is 400*cc*. per minute. In the lungs, therefore, are all the elements necessary for the generation of electricity, and the blood-stream being the carrier of energy as well as of oxygen, and iron being present in every cell, it follows that not only is "vital force" circulated throughout the body but that a measure of independent generation proceeds in every individual cell. The brain, receiving as it does six times more blood than any other part, except the thyroid gland, is the seat of highest potential, but with that we are not presently concerned.

And now let us ponder figure 1.

The exoplasm is an enveloping insulating membrane or capsule, designed principally to conserve the energy of the cell, and the cell itself is a species of Leyden jar, capable

to some extent of self-charge. The nucleus and nucleolus are always centrally situated (a fact in itself suggestive of similarly electrified bodies) and the centrosome—(the attraction sphere of physiology) is *single.*

Before reproduction can begin the centrosome must be duplicated, thus :—



The moment that occurs cell-reproduction commences, and the following changes take place with comparative rapidity.

The two centrosomes, being similarly electrified, at once repel each other and move to positions as far apart as the structure of the cell permits.

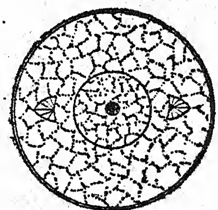


Fig. 2 (diagrammatic)

But inasmuch as the network of protoplasm would not allow of this the nucleus loses its membrane and breaks up into a skein, leaving the centrosomes free to move. They, the latter, are then, in effect, two permanent magnets with their N poles opposed and lines of force connect them as in magnetism.

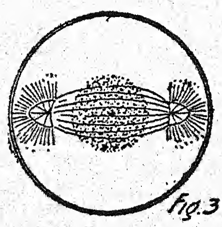


Fig. 3

Now the nucleus contains a number of threads or rod-like

substances called chromosomes and these are in the skein shown in Figure 3. They are always in multiples of two and during the process of cell-division each of them splits into two parts.

In parting with its membrane the nucleus also parts with its insulation and the chromosomes are deprived of theirs by splitting. The latter are thus, for the time being, electrically neutral or alternatively are similarly electrified bodies and are accordingly marshalled by the lines of force—the repelling influence from each centrosome—into the equatorial plane, or, in other words, into a position equidistant from the centrosomes (Figure 4).

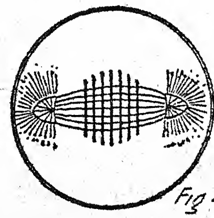


Fig 4

After a brief interval the chromosomes regain insulation and in accordance with the law governing electrified bodies (they are now oppositely electrified) are attracted in two equal groups by the centrosomes. (Figure 5).

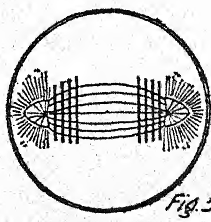


Fig. 5

Directly that occurs new nuclear membranes are formed, the exoplasm gradually contracts in the centre, the lines of force disappear and as shown in Figure 6, two daughter-cells, each with a single centrosome, mark the conclusion of the process.

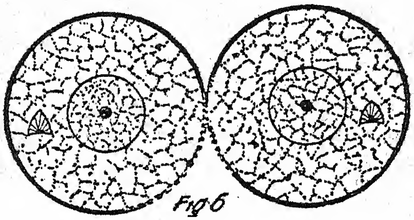


Fig 6

These cells are then said to "rest," but of course they undergo further development, and await the duplication of the centrosome, before they can further reproduce themselves.

Here, clearly, we have evidence of electrical phenomena in association with vital processes and while I have only postulated generation of force as taking place in the body it is, I think, open to question whether we inspire atmospheric air alone or whether it is accompanied by some form of energy of supermundane origin. I am led to consider this as a possibility by the facts that the earth continually receives positive charge from the atmosphere and that the atmosphere is merely the vehicle and not the source of that charge.

The conduction of the nerve impulse, upon the testimony of the galvanometer, would appear to be in accordance with the theory of the propogation of electric force by molecular action, the molecules of the interpolar wire being as follows :

Fig. 7

C being the copper and Z the zinc end, the dark parts being + and the clear parts – . The first effect of the electric force developed is to throw all the molecules of the circuit into a polar condition, the force being transmitted from molecule to molecule in both directions. Positive and negative electricities appear in each molecule of the circuit ; and if the action be powerful enough, discharge takes place

throughout the whole, each molecule giving out its electricities to those next it, which, throwing out the opposite electricities, produce quiescence throughout. A constant series of such polarisations and discharges, taking place with enormous rapidity, constitute a current.

The physiological argument against this theory is that the rate of propagation of the nerve impulse is only 120 metres per second, against, roughly, the 3,000 miles of electricity. But the argument does not hold good, because the nerve impulse is not propagated along a homogeneous wire but a long nerve which is anatomatically, though not functionally, interrupted by thousands of synaptic junctions and arborisations, at each of which the current suffers delay.

I will endeavour to make this clear as it is a very important point. A condenser, as used in telegraphy, consists of a number of sheets of tin or silver foil separated from each other by a non-conducting substance, such as paraffin wax. Now tension (electrical pressure) is in the inverse ratio to the area over which a charge is distributed. Condensers are conventionally shown thus:

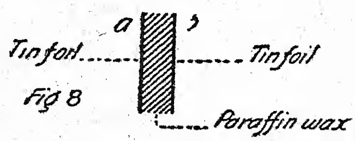


Fig 8

If we connect that apparatus in circuit with a battery:

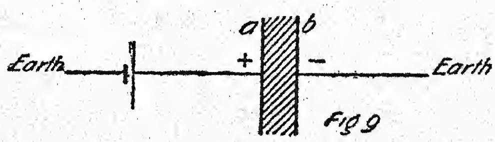


Fig 9

the plate (tin foil) *a* will receive positive charge from the battery and transmit by induction a negative charge to plate *b*. Suppose the latter to have twice the area of *a* and it will become evident that a single impulse could not charge *b* to the same potential as *a*. Not only is that so

but Nature uses impulses in several circuits at the same time so that the current-strength, though sufficient in some circuits requires amplifying in others. In all, or most of these cases, there would be delay, and as each synaptic junction and arborisation is of the nature of a condenser of varying capacity, it can be postulated with reason that no comparison is possible between the rate of propagation of the impulse along a nerve and that of a current of electricity along a line.

My difficulty is not to find proof that the human body is primarily formed for the exercise of electrical functions but to sufficiently condense that proof.

Let us now consider ganglion cells.

There are three classes of these, *i.e.*, unipolar, bipolar and multipolar cells.

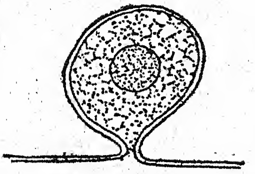
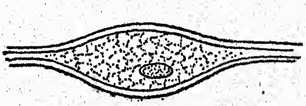


Fig 10_ Unipolar cell

The first of these are in association with the "closed" circuits of the sensory nerves only. They are really storage cells in a state of charge and their office is to maintain electrical equilibrium by "giving" or "taking" as the case might be, and to hold our store of reserve energy.

Those of the bipolar type are condensers of higher capacity than synaptic junctions, while multipolar cells are built up of a number of Leyden-jar-like rings, each of which is on a separate circuit and may be linked up with arborisations for the purpose of changing the sign of current where required.



As many of my readers will be aware all the impulses

which originate in the brain pass by the motor and secretory nerves from the brain *downwards*. Without an arborisation, or a condenser, in circuit all the impulses conveyed by the axon or line wire *a* (Figure 11) would be efferent and if passing out by the branch circuits, *b*, *b*, *b*, *b*, *b*, *b*, *b*, would also be efferent. If, however, it was desired to change the sign from positive to negative—from efferent to afferent—in any circuit it would only be necessary to insert a condenser in that circuit at some point outside the cell.

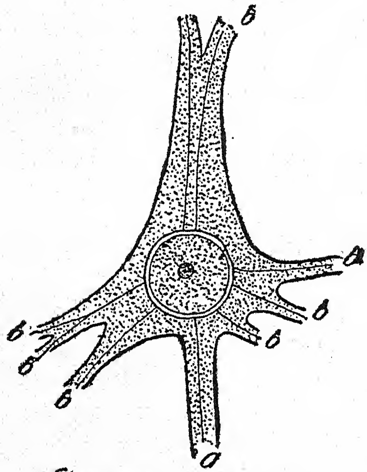


Fig. 11. Multipolar cell

That is exactly what Nature does. The only difference is that it is called an arborisation, and is shown thus :

The process is one of induction, pure and simple.

One of the strongest links in the chain of evidence is probably the heart.

The heart is nothing but a pump and a pump must be actuated by power of some description. Moreover, it must be supplied with that power, without intermittency or difference of pressure, *during every second of our lives*. What is that power ? Chemical reaction ? It is difficult to see how any series of chemical reactions can be productive of a regular and unfailing supply of power such as the heart requires. If such a thing were possible—and I do not for one moment believe it to be possible—the harmless seidlitz powder might well be fraught with danger to life.

A more reasonable hypothesis is to regard the lungs as the generating station, as I have said, and the blood-stream

as the carrier of energy. The muscular fibres of the heart are undoubtedly electrical in character and form part of an automatic system. The energy supplied to them is governed and controlled in a very wonderful way, because although the oxygen intake of man is halved during sleep the pressure, in normal health, never varies in its proportion.

To fully comprehend this we must recall the fact that by reason of its greater blood supply the brain is the seat of highest potential. From the brain issue two branches of the vagus nerve, called the cardiac branches. Their function is akin to that of a gas governor which when the water is sufficiently hot automatically lowers the flame, or increases it when the temperature of the water falls. Now the oxygen intake being halved at night the pressure of the heart's energy would, failing an arrangement of this kind, be halved also, but inasmuch as the inhibiting current from the brain along the cardiac branches of the vagi falls in the same proportion, the pressure of the energy supplied to the heart is unaltered.

It will be noted that I hold the human body to be a complicated piece of electrical apparatus, the lungs providing the battery and the nerves being, to all intents and purposes, insulated wires. Of what, it will be asked, does their insulation consist ? It consists of several substances, but mainly of the sheaths of the medullated and the lipoid coatings of non-medullated nerves; the skin resistance serving to maintain the body potential within limits consistent with the safety and comfort of the individual.

As regards the vegetable world, let us, as we have done with the human body, go back as far as we can, to the beginning of things, and study the seed; selecting, for illustration, one with which we are familiar and which is large enough for its structure to be seen with the naked eye. We will take an edible chestnut in its pod, for it is very similar in appearance to a fœtus in the womb and for that reason more than ordinarily interesting.

In normal conditions of weather the air is the positive and the earth the negative terminal of Nature's electrical system. Everything growing in the earth is negatively

charged through the roots, stems and venation, and positively by the air through the aerolæ of the leaves, so that in the roots, stems and venation the tree or plant has its negative and in the aerolæ its positive terminals. There is, in fact, an ordinary electrical circuit, *i.e.*, air to earth, and earth, through the plant, to air.

It is well-known that the vegetable cell is practically identical with the animal cell and that the phenomenon of division or reproduction is common to both. In at least one respect a seed does not differ from either vegetable or animal cell, *i.e.*, it is a potential Leyden-jar. Furthermore, as the fœtus has no separate and independent existence but is dependent upon the maternal blood-stream, so the immature seed in its pod is supported by the parent tree, and even as the cell cannot reproduce itself without electrical aid, so the seed cannot germinate or be said to live as a seed until its electrical structure is completed and it is able to receive and retain charge.

The following sketch is of a young edible chestnut in its pod, cut in section :

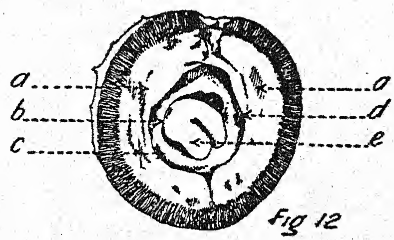


Fig 12

The letters *a*, *a*, represent a white, pithy substance, positively charged by the air ; *b* is an inner insulating membrane enveloping the seed substance, *e* ; and *d*, an outer insulating membrane. The negative terminal connects with *d*, and is the battery wire from the earth, while *c* is a moist and markedly acid layer surrounding the seed-substance, *e* ; this, it will be seen, lies between the two membranes *b* and *d*. The seed-substance itself also contains an acid secretion.

Before the seed can germinate its substance must be continually and adequately electrified. Why, then, cannot it germinate while in its pod ?

In the first place, the outer membrane, *d*, is in contact both with the negative earth-lead and the positively charged white pith, with the result that there is partial neutralisation of charge ; I say partial because the seed-substance by galvanometric test yields a feeble reaction showing weak electrification, as against the strong electrification of *a*, *a*, and *c*. Full provision is made for the protection of the seed during development. The acid, moist layer, *c*, acts in much the same way as the copper taping upon a telegraph or telephone wire, or the lymph-space around a nerve-fibre, in intercepting induced currents, so that so long as the layer *c* is conductive the seed-substance cannot receive sufficient electrical stimulus to incite it to germination.

To enable it, when mature, to reproduce its species, some change must of necessity take place, and that change is a very important one.

When a pod falls from the tree and releases the seed two things happen almost simultaneously. The outer membrane *d*, dries and becomes a non-conductor, and the layer, *c*, also dries up and forms a fibroid instead of a conducting layer around the seed-substance.

The subsequent electrical processes can now be readily understood. The dry outer membrane, *d*, provides absolute insulation for the seed until such time as it is buried in the earth. It then, in contact with the damp soil, is changed into a conductor and forms the outer coating of tin foil, as it were, of a Leyden-jar. The, now, dielectric layer, *c*, and the inner membrane, *b*, represent the insulating material of the jar and the moist, acid seed-substance the inner coating of tin foil.

A diagram will be useful.

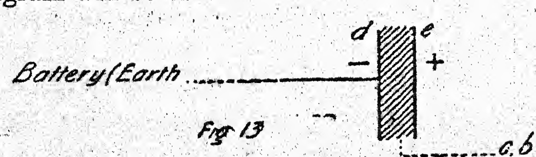


Fig. 13

It scarcely calls for explanation; *d* receives negative charge from the earth and by induction positively electrifies *e*, to a potential slightly higher than that of the earth, because *d* is of rather greater area than *e*. In this manner the seed-substance is continuously electrified and from the moment *d*, is capable of transmitting the earth current it can be said to have begun to live an independent life, given the requisite conditions of warmth and moisture.

In conclusion, we must, I think, agree that a case has been made out which goes to show that some connection exists between electricity and life, and that the popular belief that "electricity is life" is, after all, not very far wrong.

If, however, doubt continues to exist in the mind of any reader he may further inform himself upon the subject by studying plant life.

Taking as his authorities Schäfer, Hæckel, Strasburger, he will observe that the phenomenon of the segmentation of the ovum is on all fours with that of cell reproduction, that the fertilisation of the ovum of a mammal by spermatozoon is almost identical with that of an oosphere by spermatozoids and that there is no essential difference between the ovule of a gymnosperm and the pregnant human womb. Proofs can, in fact, be multiplied almost *ad infinitum*, but perhaps enough has been written to provide food for thought.

In the final chapter of his *Animal Physiology*, Dr. Carpenter writes: "We have seen that, however apparently different, the essential character of the reproductive process is the same in the highest animal as in the lowest. It has been shown that the development of the highly organised body of man commences from the same starting point with that of the meanest creature living: for even Man was once but a single cell, undistinguishable, by all human means of observation from that which constitutes the entire fabric of the simplest protozoon."

He might almost have added the "simplest vegetable organism," for the reproductive process of the cell of the diatom is practically the same as that of man.

Professor Huxley, writing "On the Physical Basis of Life"* said: "Thus a nucleated mass of protoplasm turns out to be what may be termed the structural unit of the human body. As a matter of fact, the body in its earliest state, is a mere multiple of such units; and in its perfect condition, it is a multiple of such units, variously modified. . . . . What has been said of the animal world is no less true of plants. Imbedded in the protoplasm at the broad, or attached, end of the nettle hair, there lies a spheroidal nucleus. Careful examination proves that the whole substance of the nettle is made up for repetition of such masses of nucleated protoplasm, each contained in a wooden case, which is modified in form, sometimes into a woody fibre, sometimes into a duct or spiral vessel, sometimes into a pollen grain, or an ovule. Traced back to its earliest state the nettle arises as man does, in a particle of nucleated protoplasm. . . . Thus it becomes clear that all living powers are cognate, and that all living forms are fundamentally of one character. . . . Perhaps it would not yet be safe to say that all forms of protoplasm are affected by the direct action of electric shocks; and yet the number of cases in which the contraction of protoplasm is shown to be affected by this agency increases every day."

*Methods and Essays.

CHAPTER II

THE STRUCTURE OF THE SEED

I QUOTE the following from a work of reference:—"Seed: In Botany, the mature or fecundated ovule. It consists essentially of the young plant or embryo, enclosed in integuments, of which there are two. It varies much in form; thus it may be *rounded*, as in the water cress; *reniform*, as in the poppy; *obovate*, as in the larkspur, etc., similar terms being employed in describing these forms to those applied to like modifications of other organs. The outer integument or seed-coat is termed the *testa* or *episperm*. It is usually of a brown or somewhat similar hue, as in the almond; but it frequently assumes other colours. It varies in texture, being soft, fleshy, membraneous, coriaceous, etc. It is often curiously marked with furrows, ridges, etc., and often furnished with hairs, spines, wings, and other appendages. The inner integument is called the *tegmen* or *endopleura*, it is generally of a soft and delicate nature. A third integument, more or less complete, is occasionally found on the surface of the others. The inner portion of the seed, called *nucleus* or *kernel*, may either consist of the embryo alone, as in the wallflower and the bean, or of the embryo enclosed in albumen or *perisperm*, as in the pansy. When the nourishing matter called the albumen is present, the seed is said to be albuminous; when it is absent to be ex-albuminous."

All dry seeds that I have examined, and they have been many in number, are, broadly speaking, of the same physical structure. This consists of an outer coat of varying thickness and density, an inner fibroid lining and a membrane of a lipoid nature completely enclosing the seed substance; which latter has a certain liquid and generally markedly acid content.

Some months ago I investigated and reported upon the

Wulfryn process of seed electrification and a quotation from that report may not be out of place here. I said:

"During such time as the seed is in process of development it is as dependent upon the mother tree or plant as the unborn child is upon the maternal blood-stream, and precaution is taken against premature germination by withholding from it a perfected electrical system; so soon, however, as it begins, so to speak, an independent existence it—and I am including all seeds—becomes a species of Leyden jar, in order to enable it to receive from the earth, when in its proper environment, the continuous induced electrical charge essential to germination.

"This I sought to make clear at the recently held meeting of the British Association. In its resting stage, that is to say before it is sown, the seed consists of a dry outer membrane—the seed coat—and a fibroid or lipoid layer between it and the seed substance itself, which latter is enclosed in another, and usually thinner, protective membrane. In that condition it is electrically inert. Before growth can commence the seed coat must be rendered conductive. When that is done, by placing the seed in contact with the soil, the seed coat becomes the outer layer of tinfoil, the inner fibroid or lipoid lining, together with the inner membrane the glass of the Leyden-jar, and the seed substance itself, with its moist and generally acid content, the inner layer of tinfoil. The electrostatic capacity of the seed is therefore a matter of very great importance, and this is governed by (1) the resistance of the seed coat, (2) the specific inductive capacity of the fibroid or lipoid dielectric, and (3) the nature and quantity of the liquid content of the seed substance.

"A marked difference exists in detail between, for instance, wheat, oats, barley and rice, but it is mainly in the arrangement of the starch grains. In principle all seeds are the same, and in them all the embryo radicle, plumule and cotyledons must, if one seed is to be as good as another, be equally developed.

"This, obviously, cannot be the case. Some seeds are blown down by the wind, others are affected by predatory insects or by disease, while others again are immature when

garnered. Taking, for example, the age of matured seed to be ten months, we have them, in practice, of all ages from. possibly, four months upwards.

"If a large number of seeds—any seeds—is sown, the most casual observer must have noticed that they neither germinate at the same time nor produce uniformly vigorous plants. In every sowing there must be a percentage of loss.

"The Wulfryn process consists in placing the seed to be treated in a bath containing a suitable metallic salt such as calcium or sodium chloride and weakly electrifying the same for a length of time appropriate to the seed under treatment. The solution is then run off, and the seed taken out and dried.

"The object of the salt is not only to decrease the resistance, or, in other words, to increase the conductivity of the seed coat, but to maintain that conductivity during the period of germination. Calcium and Sodium in correct proportions are, moreover, plant foods and assist in the after stimulation of root production.

"Such, in brief, is a description of the process, but, simple as it appears to be, there is danger of failure if it is handled by inexperienced persons.

"The present practice is to dry the seed, by heat, upon the floor of a malt kiln. Failure, in my opinion, can only be due to over-heating, which, by diminishing the liquid content of the seed substance must lower the electrostatic capacity, and therefore the vitality, of the seed. In a lesser degree undue hardening of the seed coat would tend to interfere with, or at least delay, germination.

"Successful drying by heat is dependent upon the two factors of time and temperature, both of which are in turn dependent upon human intelligence. Drying by air in motion would eliminate both factors and render the process as nearly automatic as such a process can be made.

"It may be imagined by those who have but an elementary knowledge of applied electricity that the treated seed, when dried, is in a condition of comparatively high electrification. That, clearly is not the case.

"During such time as the seed is under treatment it is raised to a potential much higher than that of the air, but upon removal from the bath and in the course of drying all or nearly all of the added charge must be given off. As well expect a Leyden-jar to retain its charge after the inner coating had been "earthed."

"In what way, then, is the treatment beneficial?

"I did not know, until a long series of experiments had been carried out. The first fact of importance to be demonstrated was that *the effect of electrical stimulus continued after disconnection of current,* and the second that *such stimulus tended to advance the development of the embryo plumule, radicle and cotyledons.*

"Subsequent investigation satisfied me upon both these points and made it evident that as an actual result the seeds were rendered far more uniform in the matter of development than they were before treatment, and that the percentage of loss to which I have referred should be largely avoided.

"In other words, the effect of the process is to *mature* the seed.

"I have before me a paper (*Annals of Applied Biology,* Vol. VI., No. 1), by Drs. Kidd and West upon "The Influence of the Physiological Condition of the Seed upon the Course of subsequent growth and upon the Yield," in which it is suggested that treatment of seeds in water as well as in solutions of various acids and salts beneficially influence the final yield. That is quite possible. Anything, so long as it is not injurious to the seed, which lowers the resistance of the seed coat prior to sowing would be helpful. There is nothing new in it. Some seeds, such as those of the canna and bamboo, by reason of the hardness and density of the seed coat, are invariably soaked in water for forty-eight or more hours. But not only must they then be sown at once, but *the physical structure of the seed is not in any way affected by immersion in non-electrified solutions,* except that bulk may be slightly increased by swelling. Too prolonged immersion may also interfere with the resistance of the fibroid or lipoid inner layer, to the detriment of the seed."

Let us, however, examine some seeds in detail both before and after they arrive at maturity, selecting for the purpose such as are fairly large, and commencing with the horse-chestnut, or "Conker" of our boyhood.

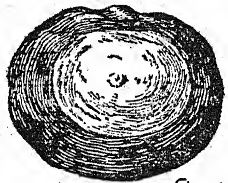


Fig. 14

Before we consider it in its character of a finished article it will be as well to see it in its pod, in process of manufacture. In the above drawing a patch of lighter colour will be seen and in the centre of this a circular dot. Both are there for a very definite purpose, but we can return to them later.

The fundamental principle governing the germination of a seed is this: the seed substance must receive a continuous charge of electricity; this charge must be induced or the seed would rot, and no such charge can be imparted until the seed becomes in effect a Leyden-jar. Water, air and warmth are of course necessary, but these also are in electrical connection; water to give conductivity and aid in the formation of protoplasm, air to complete the circuit and warmth to facilitate conduction.

The next drawing is of an immature seed in its pod.

Fig. 15

a is what is left of the stalk—the battery wire conveying negative current from the earth; *b* is white pith with an acid secretion, positively charged by the air; *c* is a moist and markedly acid layer surrounding the seed substance *d*;

e is an outer membrane or seed coat which afterwards turns brown; *f* an inner membrane or skin covering the seed substance, and *g* the wall of the pod. The seed itself lies in a bed of chemically neutral white pith.

The stalk, the battery wire, makes contact with the seed at the circular dot in the middle of Figure 14.

While it is in its pod the seed substance must not be electrified sufficiently to cause it to germinate. As yet it is not ready to begin an independent existence.

What are the precautions taken by Nature to prevent this?

The earth supplies current as far as the seed coat; the layer *c* would take the place of the outer coating of tinfoil, the inner membrane *f* the glass of the jar, and the seed substance *d*, which also contains an acid secretion—the inner coating of tinfoil. Why, then, is not the seed adequately electrified.

The reason is simple. In the first place, the layer *c* intercepts the charge; secondly, the patch of lighter colour on the conker is of much lower resistance than the inner membrane and therefore offers an easier path of escape than the forced one of induction through the inner membrane. We have a better view of the layer *c*, in the following sketch of a younger seed and it will give us a clearer idea of the stalk connection:—

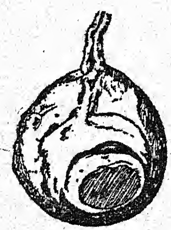


Fig 16

As a result the seed substance receives a very gentle electrical stimulus, sufficient to enable it to grow, but quite insufficient to urge it to premature germination.

But when it has ripened, and the pod, falling, has split segmentally and ejected the seed, a very important change

takes place. The brown seed coat dries and becomes a non-conductor and the moist layer *c*, also dries up and interposes a layer of non-conducting fibre between the seed coat and the inner membrane *f*. We have then the Leyden-jar minus its outer coating of tinfoil, and without that coating no inductive action can occur.

That is to protect the seed until such time as it is buried in the soil. When that happens moisture transforms the seed coat into a conductor and the Leyden jar is an accomplished fact. The seed coat is the outer coating of tinfoil, the fibroid lining, *c*, and the inner membrane, *f*, the glass, and the seed substance the inner coating of tinfoil; air in the soil completing the circuit.

If the seed is cut in section a knob-shaped piece, like the end of a dumb-bell, will be noticed and as growth commences at this point it would appear that the embryo radicle and plumule are ensconced within it.

Next in order we will take an acorn.

In its electrical aspect this seed is practically identical with the horse chestnut except that the seed coat is not so fully closed at the apex as to be airtight and it has not therefore the keeping qualities of the chestnut. In other respects also there are differences between the acorn and other seeds. For example, the seed substance of the hazel nut, which it resembles, mostly remains whole during germination, except at the point where the radicle and plumule emerge, but the acorn is formed of two halves within the inner membrane, and the radicle is connected with each half by a band or tongue some 3/32nds-inch in width. The cotyledons of the horse chestnut plant grow from the inner margin of the seed substance and the central portion, at a certain stage of growth, becomes detached and, if handled, falls away.

Acorns are always connected in series upon the parent oak. The stalk is a continuation of the (earth) battery wire and inasmuch as the seeds do not, whilst adherent to the tree, receive a static charge but a direct and continuous supply of current the circuit is completed by a point at the apex of the seed being left open to the air. The following

illustration will serve to show the electrical connections, although it is not a good example of the series method.

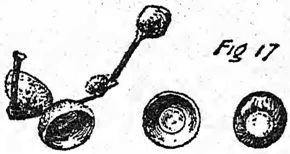


Fig 17

The earth lead is direct to the cup upon which the acorn is seated, and the contact upon the latter is clearly shown.

Before I go any further it will be well to state exactly what I mean by "static" charge; the word "static" may be taken too literally.

Static electricity is said to be electricity at rest. Theoretically it is so. Practically it is not, it is only comparatively at rest, because if it were really so it would argue perfection of insulation and that is non-existent. It is really a matter of relative resistance of parts of the circuit. If a Leyden-jar is charged it does not retain its charge indefinitely. That it does so at all is due to the high resistance of the path to earth (the air), but it gradually loses charge by convection.

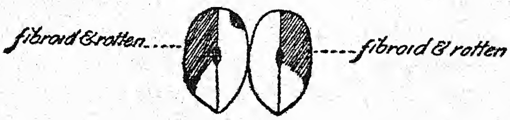
In taking the insulation test of a submarine cable the distant end is freed—by suspending it in the air—or sealed, and the cable is then charged with a known electromotive force for a certain number of seconds and the discharge observed upon the scale of a galvanometer; comparison being made with a condenser of known capacity. The discharge shows a loss of current, due to leakage through the gutta-percha to the earth. Without leakage there would be no circuit and where there is leakage there is electricity in motion, although it is slow motion. Now there is always leakage—to a greater or a lesser extent—where electricity is concerned and electricity in motion is electrical energy. Germination therefore calls, in my opinion, for an expenditure of energy and not mere electrical pressure, which is all that a purely static charge could exert. The resistance of the inner membrane is certainly not greater than that of gutta-percha and is probably much lower, while air is present in the soil. The absolute insulation of the seed

substance, however, is, doubtless sufficiently high to ensure adequate electrical tension.

In *Studies in Electro-Physiology,* I stated my belief that puncture of the inner membrane of the acorn—or indeed of any seed—would prevent germination by reason of interference with its electrical structure. The experiment had not then been tried but as it was a point which called for settlement, I perforated a number of acorns, using for the purpose an ivory stylus.

Generally speaking this could not be otherwise than fatal because with the perforation of the insulating membrane the electrostatic capacity of the seed would be lost. But such curious provision seems to have been made by Nature for all sorts of accidents and unfavourable conditions that if animal instead of vegetable life were concerned we should suspect intelligence. The "repair outfits" of vegetables and fruits has been frequently mentioned by me and it now remains to be seen what happened to a number of acorns which were pierced to the centre of the seed and then potted and left for six weeks before examination.

The first, which fairly represented all the others, with one exception, presented the following appearance:



Degeneration proceeded rapidly and it was abundantly evident that the seed was dead.

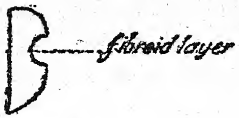
But in the case of the exception above-mentioned a very extraordinary thing had occurred. This seed had germinated and protruded a radicle four-and-a-half inches in length, although there was no visible sign of the plumule.

It gave me a very bad quarter of an hour, for notwithstanding the failure of the others it seemed, upon the face of it, to be subversive of my theory of electrostatic action and to render all my work abortive.

But closer scrutiny brought relief. The hole made by the stylus had been accidentally plugged with clay in the course

of potting and that rough measure of repair the seed had improved upon by forming a fibroid layer to cover the hole, rendering it continuous with the inner membrane.

In section it appeared thus:



That, to my mind, sufficiently proved the point. The insulation of the seed must be intact if germination is to take place and I imagine that the plug of clay filled the temporary purpose of enabling metabolism to proceed.

We have duly noted the fact that the seed requires warmth as well as moisture and oxygen to enable it to germinate and the degree of warmth is, I take it, in accordance with the chemical secretion and physical structure of the seed. In cold weather not only is the resistance of the electrolytes in the soil increased so that less current is present in the environment of the seed, but the resistance of the liquid content of the seed substance is also enormously increased; two conditions which militate against that full measure of electrification upon which germination is dependent. Free oxygen has the same important part to play in development—from the pollen to the mature plant—as it has in the development of the animal cell into the adult animal body. As the mother of the unborn child could not sustain life in it or in herself without oxygen for the generation of nerve force, so the mother plant needs it to reinforce the supply to the ovules and to the seeds, while the seeds themselves could not develop the plumule and therefore become plants without it.

So far I have only spoken of the seed coat as the outer coating of tinfoil of the Leyden-jar, but it undoubtedly has other uses and purposes, such, for instance, as affording protection from enemies and from accident, and particularly in preventing an excess of moisture from reaching the inner membrane and so tending to break down its resistance, although this danger is specially guarded against by its composition.

Let us now consider the walnut, and its pod.

It has often been said that the tendency of modern scientific thought is towards materialism. To my mind that is incomprehensible. The student of the electro-physiology of animate nature finds a sermon in every seed and a revelation of the wonderful work of the Creator in everything that lives.

More particularly and clearly is this brought home to one when those inhabitants of the vegetable kingdom which are designed for food come under notice. The horse chestnut is a seed, pure and simple; the edible chestnut something more. Both are electrical throughout, but their structure and equipment differ. The walnut resembles neither of them, in its entirety, but has features in common with the edible chestnut, the hazel nut, the acorn and, I have no doubt, many other and similar products of Nature.

Before describing the electrical construction of the walnut, however, I should like to call attention to a matter which hitherto I have not thought to be within my purview, but which may, upon further investigation, be found to be in electrical association. I am referring to colour, to which subject a fellow student, Dr. A. White Robertson, has given prominence in his *Studies in Electro-Pathology*.

Chlorophyll is known to be developed in the presence of light, and we are aware, or have been told, that most of the chemical changes which take place in the plant occur through chlorophyll. Furthermore we know, from experience, that deprivation of light involves loss or absence of chlorophyll in the leaves of many plants with which we are familiar, such, for instance, as the *Aspidistria*.

Now the outer perimeter of the pod of the walnut is rich in chlorophyll. Inside the outer skin is a positively charged moist layer, some 3/16ths-inch thick, also containing green colouring matter of the exact tint of chlorophyll. Between that and the shell is a white membrane—a membrane free from colour. Nor does the mature shell contain green pigment.

But at an early stage of development the embryo shell presents itself as a moist layer, about 3/32nds-inch thick,

also rich in green pigment and highly electrified, while the membrane to which I have referred, is white. If the green pigment is chlorophyll it must be electrically as well as optically influenced; otherwise I am at a loss for an explanation of the phenomenon, the embryo shell being in a state of absolute darkness, as well as the membrane.

We may now have a look at the walnut in its electrical aspect, commencing with a longitudinal section of the nut in its pod.

Fig. 18

SECTION OF WALNUT.

a, cavity; *b*, seed substance; *c*, positive moist pith; *d*, non-conducting dry fibre; *e*, negative terminal; *f*, negative tongue; *g*, positive terminal.

As in the case of the horse and edible chestnut, the hazel nut and the acorn, the seed substance is only feebly electrified and the secretion acid; in this instance, mildly acid. The negative terminal—the stalk—connects with the tongue-like piece, *f*, and the negative system appears to be confined to this and to terminate at the dry fibrous, semi-spatulate point, *h*, which, with its wings, insulates it from the positive part, *c*.

Fig. 19

WALNUT SHELL AND NEGATIVE SYSTEM.

Viewing the first sketch in plan the moist positive pith, *c*, surrounds the negative tongue, *f*, and there is little or no doubt that this is charged directly by the air through the shell, which at all stages within the pod is conductive.

The pod itself is composed of three layers, *i.e.*, the outer hard, but thin green coating, then a moist layer, 1/8th to 3/16ths-inch thick, and a thin, *white* inner membrane lining the cavity in which the nut lies. The second layer is positive and connects only with the flower end of the pod.

The inner membrane of the pod, instead of being chemically neutral, as in the case of the horse chestnut, is markedly acid and it will be seen that when the nut is removed from its pod the posterior half of the shell—calling the flower end the apex—is always wet. I take it, therefore, that up to and including this stage induction plays no part in the electrification of the seed substance, but that the pod is directly charged by the earth and the air, and that precautions are taken, as before, to prevent more than a fraction of that charge reaching the immature embryo. Corroboration of this view is furnished by the third sketch which shows the embryo shell in the form of a moist, green pigmented layer, *i*, about 3/32nds-inch thick, between the membranous covering of the seed substance and the inner membrane of the pod.

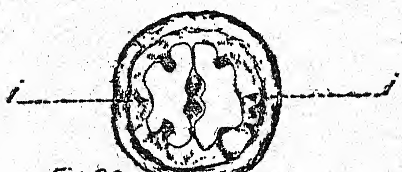


Fig. 20

WALNUT.—Transverse Section.

After removal from the tree and therefore disconnection with the earth, the pod in which the seed is contained continues to receive charge from the air but it has fulfilled its purpose and thereafter induction is necessarily a factor in the life history of the walnut.

Both as a seed and a food, but more particularly in the latter regard, it is interesting to observe the measures taken

by the Great Electrician to safeguard it from the possibility of premature germination and decay. This is achieved by balancing the negative and positive electrifications and providing the seed substance with a tough highly resistant, air-tight envelope or membrane. When, however, the nut is discharged from the pod and buried in the earth, the shell, and the pith within it become negatively electrified and so the conductive seed substance in its insulating membrane obtains by induction the continuous electrical charge without which germination could not proceed.

As the inner membrane of the pod, together with the middle layer, is markedly acid and is connected electrically with the remains of the flower we can see in what manner positive charge is conveyed to the acidulated pith, *c*, and divine the purpose and meaning of the cavity, *a*, with its non-conducting fibrous lining.

The stalk is somewhat remarkable for the comparatively large sectional area of the conductor.

In a specimen before me the section has an outside diameter of 3/16ths-inch, the conductor being stained with green pigment, and an inside diameter of 1/16th-inch, exactly centred. It, in fact, presents the appearance of a section of a heavily insulated metallic conductor; the material surrounding the earth-lead being fibroid in character and darker in colour.

In regard to what I have termed a "repair outfit" lost insulation is partly, if not fully regained by the exudation of wax upon the cut surfaces—a feature it possesses in common with other nuts—while long life is ensured to the seed substance by an ample liquid content and its tough air-tight membranous envelope.

Fig 21

SECTION OF WALNUT.—With positive pith, *c*, removed.

The last drawing shows the nut with the positive pith, *c*, removed; the dark space on either side of the seed substance giving an idea of its extent. On the right may also be seen a portion of the fibrous membrane in which it is enclosed, and at the apex the remains of the flower.

In conclusion, the careful student will not fail to note that whereas in the horse and the edible chestnuts no traces of the flower appear, their structure differs electrically from that of the walnut and that the flower opening is in their case unnecessary.

CHAPTER III

UPON ELECTRICAL STIMULI GENERALLY—AND IN RELATION TO SIGN OF CURRENT

WE have remarked that the tendency of seed electrification is to mature or advance the development of the embryo but when we ponder the application of electricity to horticulture and agriculture the first and most important thing to bear in mind is Nature's own method.

The air is the positive and the earth the negative terminal of the natural electrical system, and the current is continuous, not alternating.

We may improve along those lines, but if we depart from them we shall, I think, waste time.

Now, positive air and negative earth mean that there is, in normal conditions of weather, a downward driving force, with a return through the roots, stem and venation of the plant; the aerolæ of the leaves taking in oxygen—plus air electrification and light energy to stimulate them to growth.

Light energy is not yet fully understood but it is to be reckoned with because we know from experience that it is too powerful for young seedlings, which require to be shielded from it.

When plants are grown in pots they are cut off from the negative earth current and the moist soil in the pot, possessing, as it does, capacity, takes its charge from the positive air, and the plant reverses its polarity, becoming positive where an earth-grown plant is negative and *vice versa.* The effect of this is to stimulate upward growth, and were the electromotive force higher there would be very little root production. Such plants are not, in fact, grown naturally and would be far better if the soil in the pots could be connected, by means of a metallic conductor, with the earth; other things, of course, being equal.

To show that this is not mere theory I will give an account of experiments carried out during the past two years.

There is, I need hardly say, a great deal of difference between seed electrification and electrification of the soil. When the so-called electrified seed is sown it is not electrified, but is just an ordinary seed in a state of maturity, and with germination and the consequent rupture of the inner membrane it ceases to possess electrostatic capacity, becomes a seedling and takes its charge direct from the earth, first through the lower end of the radicle and later through the filaments which the radicle throws out. But when electricity is applied to the soil there is continuous electrification of the seed and of the seedling also and the electromotive force and sign of current incidental to that added stimulus should be studied and their effect observed.

In *Soil Conditions and Plant Growth*, Dr. Russell writes upon the supposed stimulation of plants by electricity, heat and radium, as follows:

"THE ELECTRIC DISCHARGE. It has often been stated that an electric discharge increases the rate of growth of plants either by direct action on the plant, or by indirect action in the soil. As far back as 1783 the Abbé Bertholon constructed his *electro-vegetometre*, a kind of lightning conductor that collected atmospheric electricity and then discharged it from a series of points over the plant. The view that atmospheric electricity is an important factor in crop growth has always found supporters in France. Grandeau stated that plants protected from atmospheric electricity by a wire cage made less growth than control plants outside. Lesage confirmed this observation, but found that silk thread caused as much retardation as wire, so that the effect is not necessarily electrical: in point of fact the rate of evaporation was considerably less under the cage than in the open.

"Instead of relying on atmospheric electricity Lemström generated electricity on a large scale and discharged it from a series of points fixed on wires over the plant. This method has been used at Bitton, near Bristol, and studied on the electrical side by Sir Oliver Lodge, on the botanical side

by J. H. Priestley, and on the practical side by J. E. Newman.

"Numerous field experiments are recorded, but there is usually some uncertainty about the check plots. The Bromberg experiments gave negative results.

"VARIOUS RAYS. Recent experiments by Miss Dudgeon are quoted by Priestley to show that the rays of the Cooper-Hewitt Mercury Vapour Lamp have a very stimulating effect, accelerating germination and increasing growth to a remarkable extent. Priestley found that the rays from a quartz mercury vapour lamp were harmful at close range" (too violent a discharge) "whilst further off they stimulated growth. There is great scope for work in this direction; the problem is of great economic importance, because of the enhanced value of early crops.

"EFFECT OF HEAT. Molisch has shown that perennial plants steeped in hot water towards the close of their deepest period of rest come at once into activity. His hypothesis is that the "rest" required by plants is of two kinds, the *freiwillig* rest, due to external conditions and therefore capable of being shortened, and the *unfreiwillig* rest, inherent in the nature of the plant. Parkinson has tested the method with satisfactory results; spirea, rhubarb, seakale, etc., steeped for twelve hours in water at 95° at the end of November or early in December, made rapid growth when subsequently forced."

This I can quite understand as numerous experiments have shown that the impetus to growth given by any stimulus beneficial to the plant—or seed—continues for some time after the stimulus has been cut off.

"EFFECT OF RADIUM. Among the many remarkable properties of radium it was perhaps natural to expect that it might have some definite effect on plants, and even, under suitable conditions, cause sufficient increase in the amount of growth to justify its use in horticulture and agriculture. The early observations of Dixon and Wigham at Dublin, however, did not seem very promising: one hundred seeds of cress (*Lepidium Sativum*) were uniformly distributed on an even surface of moist quartz sand, and after germination had taken place, a sealed tube containing five mgs.

of radium bromide was set one cm. above the central seed. The seedlings grew up, but without any curvature, indicating positive or negative "radiotropism," and the only noticeable effect was a slight depression of growth in those within one cm. radius of the tube. As stronger preparations of radium became available more definite retardations and inhibitions were observed; thus Gager, in an elaborate report, noted a more or less complete inhibition in cell activities in younger and especially embryonic tissues, with a few exceptions. The action of radium through the soil, however, was different; germination and growth were both accelerated, and the plants farthest away were stimulated most. Acqua found that different plants, and even different organs of the same plant, were differently affected, the root system in general responding more markedly than the aerial parts, and in his experiments being arrested in their development. . . . .

"These and similar results naturally suggested that the residues left after the extraction of radium, but still containing radio-active material, might have definite manurial value, and it was not long before definite statements were forthcoming. Baker claimed that increased yields of wheat, and radishes had been obtained by mixing one part of radio-active material . . . with ten of soil. It is true that Stoklasa's results were negative . . . but this did not prevent the introduction of radio-active fertilisers, and the enterprising syndicates and companies concerned were by no means loth to push their wares. These were investigated by Martin H. F. Sutton, the experiments being made with radishes, tomatoes, potatoes, onions, carrots, and marrows, some grown in pots, others in plots out of doors. Eight different radium residues were used, in addition to pure radium bromide; the dressings were so arranged that the equivalent quantities of radium were given in each case (1/400th gm. radium bromide to 15-lbs. of soil: $2\frac{1}{2}$ times this amount per square yard to the plots).

"In no case was there any clear evidence of increased growth: even the pure radium bromide seemed to be without action.

"We are therefore left with the apparent discrepancy already observed. . . . The work of the physiologists, assuming it to be sound, certainly indicated that radium emanation is capable of stimulating certain cell activities. Sutton's results show that such stimulus, if it exists, does not affect the final growth of the plant. This discrepancy is periodically confronting the agricultural investigator."

I know as little about radium as most people, but it is said to discharge an electroscope and the alpha rays are stated to be positively charged. An effect upon animal cells has been that of over-ionisation which may certainly be called stimulus but which when applied to normally ionised tissue might well lead to a multiplication of centrosomes and the exaggerated and irregular form of mitosis associated with cancer.

As regards the rest of the quotation I have made from Dr. Russell's valuable work I need only say that for the most part the experiments he describes as having been attended by negative results are more indicative of groping in the dark than of following and attempting to improve upon natural laws.

Writing upon the stimulus of light, Bose (*Comparative Electro-Physiology, p.* 557) instances the very interesting experiment of Sach's, in which a long shoot of *Cucurbita* was made to grow inside a dark box, the rest of the plant being exposed to light.

"The covered part of the plant, under these circumstances, showed normal growth of stem and leaves. Normal flowers and a large fruit were also produced in the same confinement. The tendrils inside the box, moreover, were found to be fully as sensitive as those outside. The transmission of stimulus by the plant, in such a way as effectively to maintain such complex life activities as motility and growth, even in the absence of direct stimulation, is thus fully demonstrated. And we may gather an idea from this fact of the fundamental importance, to the life of the plant, of those nervous elements by which this is rendered possible.

"One of the most important functions of the venation of the leaf, not hitherto suspected, is now made clear to us.

Among external stimuli, none perhaps is so essential, or so universally and easily available to green plants, as energy of light. And we now see that the fine ramification of fibro-vascular elements over as wide an area as possible in the leaf, provides a virtual catchment-basin for the reception of stimulus. The expanded lamina is thus not merely a specialised structure, for the purpose of photo-synthesis, but also a sensitive area for the absorption of stimulus, the effect of which is gathered into larger and larger nerve-trunks, in the course of its transmission downwards into the body of the plant."

That hypothesis, however, is not supported by the fact that the venation of the leaf is of negative sign, whereas light energy cannot be otherwise than of positive sign; the air sign.

Professor Bose favours the absorption theory, animal and plant are accumulators, dependent upon some outside source of energy for their activating force. Acceptance of that theory would not only involve complete disregard of the electrical interchanges between atmosphere and earth which are constantly taking place, and their unchanging polarities, but would enforce the belief that Nature places sole dependence upon a form of energy which not only varies in intensity almost from moment to moment, but which, for an appreciable part of each twenty-four hours practically ceases to exist.

Upon the testimony of the galvanometer the venation of the leaf of any earth-grown plant is *always* negative, and it is much more reasonable to postulate that if light-energy is absorbed, as I have no doubt it is, in combination with air, absorbed, it is a function of the aerolæ and not of the venation of the leaf. The earth-current may be shut off by the leaf being removed from the plant, or the tree, and light may be temporarily shut off without the leaf dying. But so long as it is not deprived of air it will continue to live until, by reason of loss of moisture, there is complete cessation of conductivity. Up to that moment the aerolæ take in positive charge and the venation remains, by induction, negative.

With Professor Bose's conclusion, however, I am thoroughly in agreement. He says:

"It is thus seen how all parts of the plant are, by means of nerve-conduction, maintained in the most intimate communication with each other. It is, then, by virtue of the existence of such nerves, that the plant constitutes a single organised whole, each of whose parts is affected by every influence that falls upon any other."

In the experiments I am about to describe continuous current from one or more dry cells employed throughout and in most cases applied to the soil in the pot; or, in a few instances only, to the soil and the plant or object under observation.

UPWARD DRIVING FORCE. LONG SCARLET RADISH.

A number of seeds of the long scarlet radish were sown in the open ground, in a South border, under normal conditions, and an equal number in a 5-inch pot, the soil in which was electrified by means of a dry cell of 1.5 volt, positive to bottom, negative to top of soil; the pot being placed in a cool greenhouse.

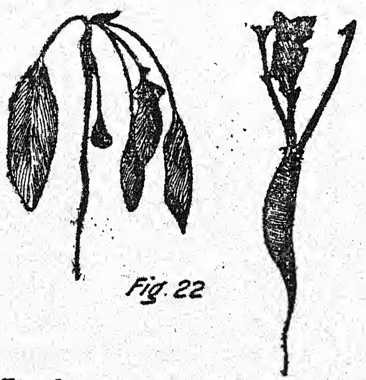


Fig. 22

The plants in the open ground showed above soil in seven days; those in the pot in four days. The former however, made much more vigorous growth. Four days later the pot plants had grown so tall and anæmic that their stems failed to support them; one having a three inch stem before forming its second leaves. In the accompanying sketch an electrified radish is seen on the left and one of the controls from the open ground on the right. It calls for no remark from me.

Grasses.

Three tufts of grass of the same species and the same size were selected and potted under exactly the same conditions in 5-inch pots; the blades being cut with scissors in each to a height of 2-inches above the soil. We will call them A, B, and C.

A was not electrified but a piece of prepared arc carbon was placed near the upper surface of the soil;

B was potted in the ordinary way as a control, and

C was electrified by means of a dry cell of 1.5 volt, positive to bottom, negative to top of soil.

All three pots were placed in a good light in a cool greenhouse and given the same quantity of water daily. Their progress was as follows:—

Nine days later—

A	Gain in height equalled				$3\frac{1}{2}$-inches.
B		,,	,,	,,	$\frac{3}{4}$-inch.
C		,,	,,	,,	4-inches.

After twelve days—

A	Total gain in height equalled				$4\frac{7}{8}$-inches.
B		,,	,,	,,	$1\frac{1}{8}$-inches.
C		,,	,,	,,	$5\frac{1}{4}$-inches.

After fourteen days—

A	Total gain in height equalled				$6\frac{1}{4}$-inches.
B		,,	,,	,,	2-inches.
C		,,	,,	,,	$6\frac{1}{2}$-inches.

A, appeared to be more robust than either of the others. The cell of C, was found to be disconnected which no doubt accounted for some slackening down.

After sixteen days—

A	Total gain in height equalled				7-inches.
B		,,	,,	,,	$2\frac{3}{4}$-inches.
C		,,	,,	,,	$7\frac{5}{8}$-inches.

After eighteen days—

A	Total gain	in height	equalled	7¼-inches.
B	,,	,,	,,	3-inches.
C	,,	,,	,,	8¼-inches.

Note.—The tallest blade of C, fell and required support.

After thirty-three days—

A	Total gain	in height	equalled	8½-inches.
B	,,	,,	,,	5⅞-inches.
C	,,	,,	,,	10¾-inches.

Note.—C, had apparently recovered from the effect of the disconnection and was making up for lost time.

Final observation was taken forty-five days after potting and the result was—

A	Total gain	in height	equalled	9-inches.
B	,,	,,	,,	6-inches.
C	,,	,,	,,	12½-inches.

From the foregoing it would appear at first sight that electrification, as applied in this instance, had had a beneficial effect upon growth. But in reality it was far from beneficial. What it did was to force abundant, hair-like growth and inhibit root production. Upon examination of the roots I found—

A Roots in dense white bands, filling the pot and protruding from the bottom.

B Similar to A, but not quite as advanced.

C Hair-like and so few in number that they were scarcely perceptible.

Some explanation of the carbon will no doubt be expected. Arc carbon when treated to increase its density—in the course of which treatment it is subjected to molecular disturbance—gives out a positive force which is clearly not electricity but which may be said to resemble it. The object of employing it in these experiments was to increase the potential of the positive charge from air to soil.

The foregoing test of grasses confirmed the view I held that electrical intensification should not greatly exceed

that of the earth and that an upward driving force would presumably stimulate upward growth, to the detriment of root production. I was not, however, altogether satisfied and determined to try the effect of difference of polarity, that is to say, using cells of 1.0 volt, connecting one with positive to bottom and negative to top of soil, and the other, as a control, with negative to bottom and positive to top.

For this experiment I took two potatoes, as nearly as possible of equal size and potted them half in and half out of the soil in 6-inch pots; call them again A and B.

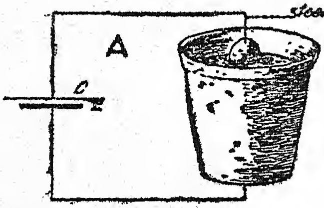


Fig. 23

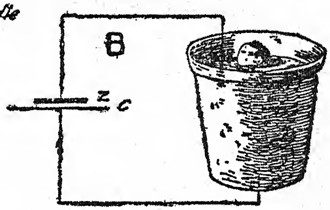


Fig. 24

Both pots were placed in a dull diffused light in the potting shed and left for thirty days, when the cells were disconnected. Examination was made one hundred and thirty-six days after potting.

B, that is the one with the upward driving force, showed nine strong shoots, $\frac{3}{8}$-inch in thickness and 1-inch to $3\frac{1}{2}$-inches high. From the base of the largest of these three other shoots branched out thus:

Fig. 25

as well as numerous filament-like upper growths. From another shoot there were thirty of these latter and from a third not only seven side growths from $\frac{1}{2}$-inch to $1\frac{1}{2}$-inches by $\frac{1}{8}$-inch, but about twenty filamentary ones. The shoots, in fact, all exhibited

this side-growth, and root-filaments appeared above the surface of the soil.

A, on the other hand, had only five shoots, none of them more than $\frac{3}{4}$-inch by $\frac{1}{4}$-inch at base, but very numerous side shoots, $\frac{1}{8}$-inch thick and at least one nearly 1-inch in length. Of these I counted seventeen, not including filamentary growths, which, however, were nearly so numerous as in B.

Removed from the pot and the soil washed away, B was seen to be destitute of root development (it having only two root-hairs depending from one shoot and these only $1\frac{3}{4}$-inches in length). The tuber was rather flabby and shrivelled.

Here the upward driving force had only manifested itself in the thick crowded upper growth to the neglect of root production and of shoots below the soil such as were exhibited by A.

Upon removing A from the pot a dense root growth was seen, with three other shoots growing upwards (making twelve in all) and there was no shrinkage of the tuber, nor any sign of young potatoes. Cut in section the tuber was perfectly firm and fresh; a slight discolouration, due to electrolysis, merely showing where the needle had entered.

B, however, when cut was not only flabby and somewhat shrivelled but both halves soon after turned brown, except in a curve from top to bottom so that they appeared thus:

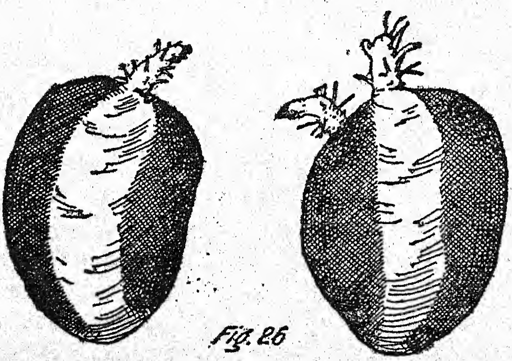


Fig. 26

The parts cross-hatched were very flabby.

For some reason which I fail to remember I did not photograph them but a rough sketch, taken at the time, will give an idea of the final appearance of the plants after separation from the tubers.

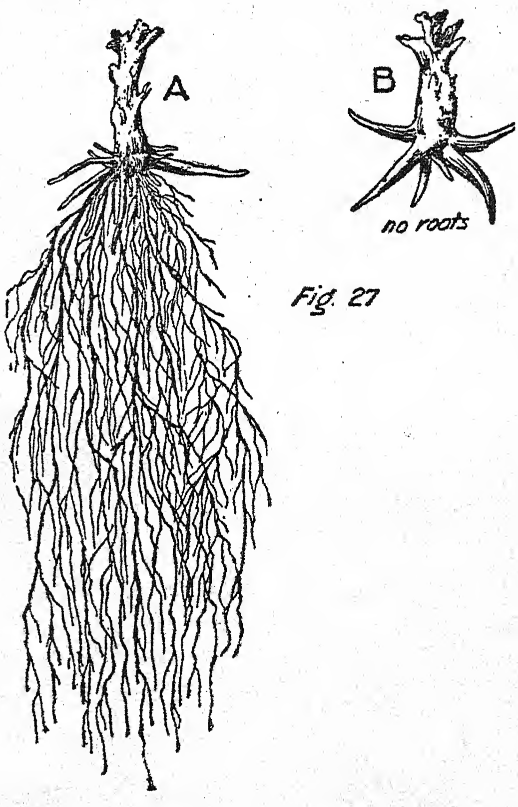


Fig. 27

In this case the abnormal upward weak growth exhibited by the radish and the grass was not repeated but the absence of root production in B, was confirmatory of the grass experiment. There was abnormal growth in both A and B and from other data in my possession I am inclined to think that the comparatively high electrical stimulus brought about a multiplication of centrosomes so that the cells instead of dividing each into two daughter cells, divided into a greater number and of the two the growth of B, that

with the upward driving force, would appear to be the most unnatural.

Tomatoes.

Experiments with tomatoes gave curious results. Com paratively high electrification (2 volts to a 10-inch pot with negative pole to bottom of soil and positive to aerolæ of leaf induced rapid growth in the lowest cluster of fruit but not in those above it. Side growths such as were observed in the potatoes of the last experiment appeared upon the stem, and the tomatoes ripened and turned red before they had attained any size. Plants in other pots, in which pieces of arc carbon had been placed just below the surface of the soil not only made good progress but were vigorous and healthy and fruited well. As, however, there were no controls the experiments possess little value.

Winter-Cherry Plants.

These were interesting. There were two plants, identical in size and condition. One was left untouched as a control and the other electrified by means of a cell of 1 volt, positive to soil and negative to aerolæ of a leaf; contact with the latter being made with a steel needle joined to flexible insulated wire.

That the stimulated plant made better progress than the control there could be no manner of doubt, but it soon became evident that 1 volt was too much for it, because the flowers displayed a tendency to fall off, and I came to the conclusion that the flowering process should not be unduly hurried and disconnected the cell for forty-eight hours. This, however, was followed by a slackening of growth and upon repeating alternate connection and disconnection noticed that the rate of growth varied accordingly, that is to say, it decreased with disconnection and increased when the current was again applied, but *not at once:* there was always an interval of inertia. After a total of ten days electrification the plant had four berries and twenty-three flowers as against the three berries and eight flowers of the

control and was taller and more umbrageous than the control.

One lesson to be learned not only from my experiments but from those of which account is given by Dr. Russell is that no matter what stimuli are used, whether the stimulus of electricity, of heat, of light, or of radium, they can only be said to benefit the plant when they are attenuated. The average electromotive force of anything growing in the earth, from the smallest plant to the largest tree, from the smallest apple to the largest vegetable marrow, is under 0.1 volt, and it seems as unreasonable and unscientific to make too wide a departure from that voltage, as it would be to largely exceed the maximum normal temperature.

As regards light we are told upon the authority of Clerk-Maxwell and Sir Oliver Lodge that light is an electromagnetic disturbance of the ether. Optics is a branch of electricity, and it is quite conceivable, and indeed probable, that the potential of light increases as progress is made from the red to the violet end of the spectrum and that there is a discharge of electricity of ever increasing intensity.

Another matter of very great importance is *sign of current.* I may be labouring the point but I have found, during the course of hundreds of experiments that reversal of the natural sign, *i.e.*, the downward driving force—invariably leads to enforced upward growth and diminished root production. In this way I have grown plants from mustard seed four feet high but there was very little root, and very few seeds. It is necessary to adhere to Nature's method and the ideal thing, in my opinion, would be to pay far more attention to light-frequencies and to restrict electrification of the air and soil to a voltage only slightly in excess of that which now obtains.

Hitherto I have only employed the prepared arc carbon to give out positive charge to soil in pots, with a view to augmenting the air-charge, and this answers better than electrification of the soil with one volt. To assist germination, however, and to help the plant to vigorous life it is desirable to oxygenate the soil, so that when the rupture of the seed coat takes place and the radicle pushes its way

downwards a supply of oxygen may be assured to the seedling.

Now carbon has great affinity for oxygen, will readily absorb it and give it out again under the pressure of water. This, no doubt, is the reason why, taught by experience, gardeners place pieces of charcoal in the soil of the pot.

Bose, whose work to me possesses only academic interest, inasmuch as I am dense enough to fail to see its practical application, says that "one mode of increasing the internal energy of a plant is by a moderate rise of temperature . . . a steady rise of temperature brings about an increase of internal energy, while a sudden variation of temperature acts as a stimulus. Thus, if we effect a sudden augmentation of temperature, this will act upon the organ, during the period of variation, as a stimulus; but afterwards, when the temperature itself, or its rate of rise, has become steady, the condition will act by increasing the internal energy of the organ."

I have the greatest possible respect for Professor Bose (*Comparative Electro-Physiology*), but while the effect of a rise of temperature may appear to increase the internal energy of a plant, it does not, strictly speaking, do so; the energy is there all the time. What it *does* do is to induce an increased *flow* of energy by reducing the internal resistance of the plant.

It is, I think, a false conclusion to come to, and false conclusions lie at the root of mistaken theory. The student might be led to believe that the additional energy alleged to be imparted to the plant was contained in heat, whereas the phenomenon was due to decreased resistance and not to augmented pressure.

The Table given (*page* 430) of "The Effect of rise of Temperature on Velocity" (of transmission of electrical impulse) sufficiently shows this:

> At 30°c. the velocity was 3.7 mm.; at 35°c., 7.4 mm., and at 37°c., 9.1 mm. per second.

Increase of energy, or of flow, is a secondary, not a primary consequence of rise of temperature and if instead

of "stimulus" we substitute the word "irritation," we can better understand what happened.

In Chapter II. I have stated that the effect of electrical stimulation continues after disconnection of current and this statement deserves attention for it has a direct bearing upon karyokinesis and upon the possible production of cancer in vegetables, as we shall see when we come to the study upon the subject.

Writing of excitations induced by light, Bose says that "energy may find outward expression, even after the cessation of the stimulus." An example of this was seen in the mechanical response of a *Desmodium* leaflet. "The plant was at first in a sub-tonic condition, and the autonomous pulsation of its lateral leaflets had come to a standstill. One of these was now exposed to the continuous action of light and its record taken. . . . Under this stimulus of light, multiple responses were initiated, which persisted for a time as an after-effect, even on the cessation of light." In taking electrical records of the after-effect of stimulation by light he obtained similar mutiple after-effects.

He expresses the opinion that "a plant or an animal is an accumulator which is constantly storing up energy from external sources, and numerous manifestations of life—often periodic in their character—are but responsive expressions of energy which have been derived from external sources and is held latent in the tissue."

That reminds me of Dr. Keith Lucas' theory of the conduction of the nervous impulse. He said: ". . . that the nervous impulse depends for its transmission on the supply of energy by the nerve along its course. If this view is correct we may be justified in supposing that by its very nature the nervous impulse is dependent for its intensity only on the conditions which it encounters during conduction and not on the intensity with which it is initiated."

As well imagine a flow of water without any difference of level, or a current, too weak to actuate the instrument at the other end, setting out upon its passage through an Atlantic cable, dependent upon the kindness of an earth-current to help it along.

Theories of that kind coming as they do from highly educated men, fill me with astonishment. Animals and plants possess considerable electrostatic capacity—that of man is equivalent to about fifteen miles of Atlantic cable—and by reason of that capacity are able to absorb energy of an electrical nature. But the plant is sustained and stimulated into growth by energy imparted to it by earth and air, while animals generate it by the act of breathing. It is not possible to kill or seriously impair the health of any animal or plant by placing it for long periods in contact with an "earth" of negligible resistance. That would effectually cut all external sources of energy, other than air.

The argument therefore resolves itself into this: "both animals and plants are dependent entirely upon air—because we do not always have light—for their existence. That is, to a certain extent, true because both animal and plant require oxygen in a diluted form for the generation of vital forces but to assume that neither are able to generate as well as to store motive power is to negative, among other things, the theory of intra-cellular generation, to suppose that iron fills no purpose in the animal and plant body and that oxygen is not in any way associated with electrical phenomena.

Air is a great factor in vegetable life, quite apart from oxygen, when it is in combination with light. An onion, for example, is a self-contained electrical cell. It may be short circuited through a very low resistance for many months without showing any sign of polarisation or loss of current. When earthed in vacuo it, as I have before remarked, soon becomes exhausted but will revive almost at once if placed in a good light in the open air; otherwise the process of recovery is slow. That goes to show that energy of an electrical nature is derivable from air. But a single fact does not necessarily establish a hypothesis, and to postulate that man is an accumulator dependent for his energy upon some external, and occasionally irregular, source of supply is hardly reasonable.

CHAPTER IV.

ACORNS

Germination and the Seedlings

Position and Arrangement of the Embryo

IN all seeds which have arrived at maturity the embryo radicle, plumule and cotyledons have been perfectly formed within the seed substance before the seed left the mother plant and were we speaking of animal bodies we could say that the fœtus had arrived at completion and awaited the moment when it could begin to live its own life.

The size and arrangement of the embryo differ with the order to which the seeds belong. As Lord Avebury tells us, there are "many whole orders in which the ripe seed is entirely occupied by the embryo; in other cases, again, as in *Delphinium*, the embryo is very small, and examples of every intermediate stage might be given.

"Where it is an advantage to the plant that germination should be rapid, this of course can be more readily secured if the embryo is large. In fact, we find that species with large embryos, such, for instance, as the cabbage or pea, germinate much more rapidly than those, such as *Umbellifers*, *Ranunculaceæ*, etc., in which the embryos are small.

"In albuminous seeds the arrangement of the embryo presents no special difficulties, as the endosperm simply fills up all vacant spaces. In ex-albuminous, on the contrary, Nature has to exercise much ingenuity, and adopt various devices to fill up the whole space."

The chief difficulty in almost every case seems to be with the cotyledons, which instead of being just ordinary first-leaves, assume all sorts of curious forms. From the last quoted source I learn that "When the testa does not readily split, and where in large seeds there is no endosperm, the difficulty of unfolding the cotyledons and extracting them

from the seed becomes great, and we arrive at cases where Nature seems to have abandoned the attempt, and, as in the Oak and Horse Chestnut, the cotyledons never quit the seed; while those of the Walnut never quit the shell."

In the Acorn the embryo radicle and plumule are contained near the apex of the seed, as in the Hazel Nut and other seeds of similar shape. Very shortly after germination has commenced they can be seen, if the seed is cut open, with the unaided eye and present the following appearance:

Fig. 28

The outer ellipse being the stalks or beginning of the cotyledons which do not in the least suggest having anything to do with leaves. To this ellipse I shall hereafter refer as the collar. And here let me remark that the first sign of germination, of life, is not the rupture of the seed coat but the visibility of the embryo; some growth having invariably taken place before it can be plainly discerned.

From the time of the first sowing in the open ground and certainly before the rupture of the inner membraneous coating, the seed substance is positively charged.

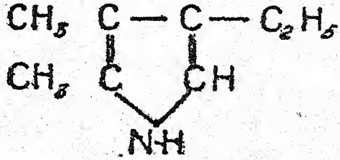
We can foresee what will happen when the seed is stimulated into life. The embryo radicle will rupture the inner membrane and take a downward course, the plumule will grow upwards—both still adherent to the seed—and in due course the first leaves will peep above the soil and come for the first time into contact with light, though not for the first time with oxygen. We may therefore usefully ponder (1) How after the loss of electrostatic capacity is the electrical system of the seedling maintained? (2) In what manner is it protected against possibly injurious light-frequencies? (3) How is it provided with oxygen? and (4) What is the probable function of chlorophyll?

We need not attempt to answer those questions in the order in which they are asked, but will endeavour to deal

with them all in this chapter. First as to chlorophyll; which in my view is to the plant what hæmoglobin is to the animal.

In *Physiological Chemistry*, Matthews says: The chemical composition of chlorophyll is not yet known. . . . When decomposed it yields, like hæmoglobin, the colouring matter of the blood, pyrrol derivatives. It is evidently related more or less closely to the hematin of the hæmoglobin, hemopyrrol being identical with phyto-pyrrol. Unlike hæmoglobin it contains no iron, but the plant must have iron for its synthesis. Its close relationship to hæmoglobin is further established by the discovery of the plant chromoproteins, phycoerythrin and phycocyan, which are crystalline conjugated proteins like hæmoglobin, but they are found in plants and are closely related to their chlorophyll. . . . It has recently been suggested that the *iron which is always present in the chloroplasts of plant cells* plays a very important part in the synthesis of the formaldehyde as well as of the chlorophyll. There can be no doubt that many colourless plant tissues, if exposed to light and if they contain iron, are able to synthesize chlorophyll." The italics are mine.

Halliburton gives the chemical formula of hemopyrrol (dimethylethyl-pyrrol) as follows:



What I am aiming at, however, is to find firm ground upon which to build up the hypothesis that chlorophyll in combination with oxygen is capable of generating force to give out energy to the plant in the possible absence of supply or in the event of insufficient supply from the earth and it is for that reason I have italicised the words "*iron which is always present in the chloroplasts of plant cells.*" Nor am I altogether convinced that chlorophyll cannot be formed except in the presence of light, or rather, is it quite

certain that no light at all is present in the upper stratum of the soil? For it is the plumule that needs it, the first leaves that seek it and these are frequently green before they emerge from the soil; so sometimes is the plumule. We should, I think, be slow in accepting the dictum that light, in the sense of an illuminating power, is alone responsible for the formation of chlorophyll and look rather to light-frequencies and the energy possibly accompanying them to further explain the phenomenon. Can we say with certainty that this energy, if it exists, is incapable of penetrating the soil? Or if the answer is "No," limit the depth of such penetration?

Next we will take the matter of the protection of the young buds from light, or I should prefer to say, from light-energy; disregarding provisions against possible enemies. Generally such protection is afforded by colour, varying from pink to crimson and russet-brown, but in some plants, such as the Oak, the colouring may include the whole of the leaves of the seedling if grown in the open ground; those in the diffused light of the greenhouse showing clear chlorophyll only, though a more delicate part of the plumule may be tinted. The buds of the Oak are protected by dry, brown stipules.

The phenomenon is particularly noticeable in the case of such ferns as the Maidenhair which have been forced. If on a bright day in the early summer one of these is removed from the greenhouse and placed in the open air in the full glare of sunlight the younger fronds turn, or come up, *red*, but later, when the fronds are stronger, this colouring gradually changes to the familiar green.

"In other cases," Lord Avebury remarks, in *Buds and Stipules*, "buds are protected by gummy or resinous secretions, as in the Horse Chestnut (*Æsculus*), the Poplar (*Populus*), Hazel Nut (*Corylus*), Honeysuckle (*Lonicera*), Currant (*Ribes*), Lilac (*Syringa*), Hornbeam (*Carpinus*), Elder (*Sambucus*) and Alder (*Alnus*), in many herbaceous plants (*Viola*, *Helianthus*, *Salvia*), and most conifers.

"The gum is often confined to the outer surface, the interspaces between the leaves being filled by hairs.

"The gum or resin is secreted by hairs, by glands, by leaf-teeth, or by the general epidermis. The gum cells are developed early, and are short-lived.

". . . The secretion may either be a gum, . . . or a resin; or both may be present together. The resin, according to Hanstein, is generally secreted in the interior of the cells, and oozes through the cell wall, while the mucus is generally the product of the epidermis. The properties and functions of the two are no doubt different. Some plants secrete both, as, for instance, the Horse Chestnut."

Now, assuming light-energy to be of an electrical, or partly of an electrical character, as I think we must assume if we believe that optics is a branch of electricity, it would appear to be necessary to afford the young leaves some measure of protection other than that of colour; to, in fact, provide for their insulation from *electrical* energy of too high an electromotive force.

When a nut, such as a Hazel Nut, or a seed, such as a Horse Chestnut, is cut in section and exposed to the sun, it throws out a secretion of a lipoid nature on the cut surfaces and also takes on a tinge of yellow or brown; not only shielding the injury from actinic rays but regaining in some degree the *insulation* which had been interfered with, just as many trees exude a gum when the bark is pierced. There is a purpose, surely, in this and it is not unreasonable to suppose that the purpose has some connection with electrical energy as a danger to young plant life.

As regards oxygen supply to the seedling before its first leaves emerge from the soil, we can agree that it is present to some extent in the soil and shall see later on how the further supply is obtained. The other question will find answer as we examine the seedling.

With the exception of those grown in the open ground the seeds about to be described were potted in 4-inch pots and kept in a cool greenhouse. Some were potted with the apex pointing downwards, some with it directed upwards, while others were laid horizontally in the soil.

The first to be examined was one of those potted horizontally, after an interval of five months.

At the point where the outgrowth issues it will be seen that it is *closely* adherent to the seed. I say closely, because this feature is not common to all seedlings. The young first leaves were bright with chlorophyll but the plumule, where it appears to be darker in the drawing, was reddish in colour.

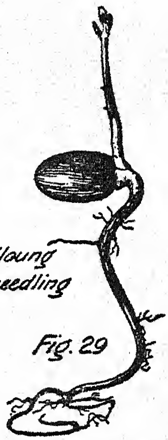

Very Young Oak seedling

Fig. 29

The radicle was covered with a tough skin which stripped like a soft bark, and the plumule was also covered with a thinner and more delicate skin.

On the seed coat being removed the seed separated into two halves.

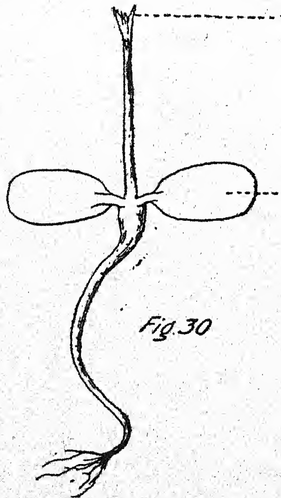


Fig. 30

The radicle was 6½-inches in length when straightened out and carried very few root filaments, except at its extreme end.

The two halves of the seed are attached to the upper part of the radicle by bands, which, I believe, are supposed to be the stalks, as it were, of the cotyledons, the latter extending along the centre of each half to the limit of the seed. Personally, I think they assist in conveying current to the seedling before the root filaments are numerous enough to supply it.

Comparison was made a few days later with an acorn which had been planted—apex downwards—in the open ground, in a South border, at the time the others were potted. It exhibited some interesting features.

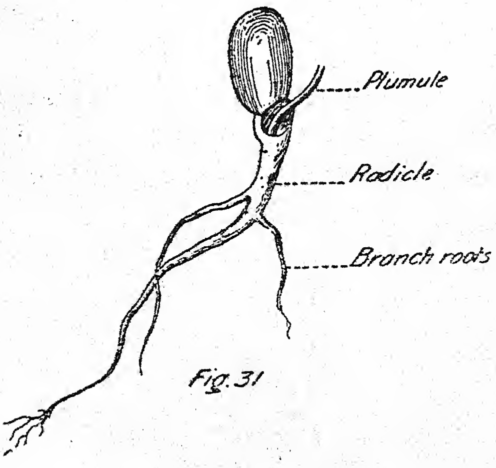


Fig. 31

There were two branch roots, 2½-inches and 1¾-inches respectively, below the collar: the radicle was 7-inches in length and the plumule had struggled only ¾-inch towards the surface. Embryo leaf buds were in evidence and perhaps helped the seedling to derive some benefit from air in the soil.

It was very noticeable that the overlapping of the collar was closer and stronger than in the last example and I concluded that a reason for this might be that the seed

being planted apex downwards, the plumule would need to make greater effort to reach the light and so need greater protection. Subsequent observation did not, however, confirm this view; although it did not negative it.

In the following week one of the horizontally potted seeds showed, as one would expect, advanced development and a more vigorous growth. There were more root filaments, but no branch roots. Additional leaf buds were seen at various points along the plumule, to which they were closely adherent instead of, as in the Hazel, being borne on stalks.

A fourth seed—one potted with its apex directed upwards—gave me an unpleasant surprise. So far as could be seen the radicle and plumule had issued from different parts of the seed and the collar was conspicuous by its absence.

I had been quite clear that the outgrowth was continuous, and that anatomically, if not functionally, the stem was a continuation of the root. And here was a specimen in which the plumule emerged from one part of the seed and the radicle from another. It was unbelievable.

Fig. 32

"An escape from this dilemma," as Dr. Waller puts it, would be to say that while the stem is generally considered to be a continuation of the root at least one instance has been known where they were anatomically distinct!

Fig. 33

However, removal of the seed coat explained the mystery. The plumule—meeting perhaps with some obstruction, such as a stone, in the soil had curved inside the seed coat and first descending had made a complete *volte face* to the surface.

So that after all it differed in no respect from its predecessors, except that owing to the necessity for the curve the growth of the plumule was abnormal; its length being proportionately much greater than that of the radicle.

Seven days after inspection of the above I selected a plant, the seed of which had been potted apex downwards and which had put forth several additional leaves.

Upon stripping the seed coat the two halves of the seed fell apart and revealed nothing new except that the bands or collar had grown more into the seed substance and that there seemed a line of demarcation between the top of the radicle and the junction of the plumule with the collar.

There were some additional leaf buds and numerous root filaments. The radicle was 7-inches in length, and single.

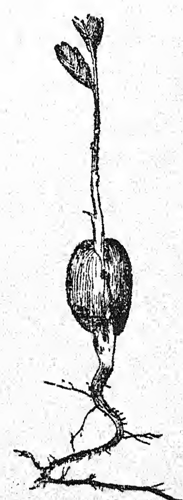


Fig. 34

The following is a sketch:

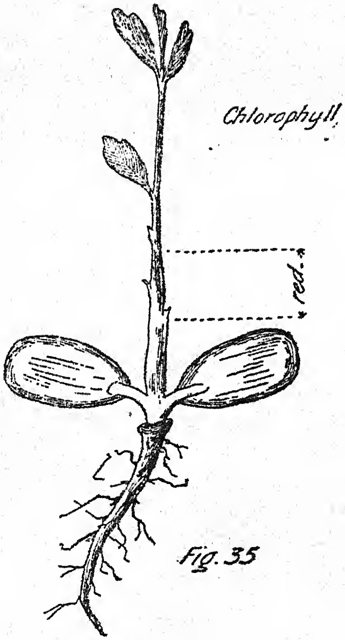


Fig. 35

After another and similar interval a plant was taken, the seed of which had been potted apex upwards. The plumule, including the leaves, was 5-inches high, and the radicle (extended) $10\frac{1}{2}$-inches in length; the latter, as may be seen, had had to execute a curve to make its way downwards.

Fig. 36

The seedling itself was perfectly healthy and, of course, more advanced in growth. Dissected, the collar was found to be green stained, presumably with chlorophyll, and the seed substance partly decayed at its posterior part, thus :

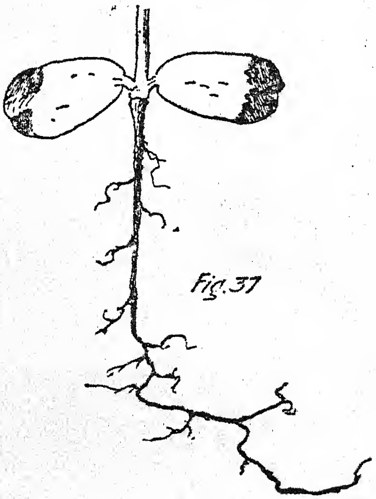


Fig. 37

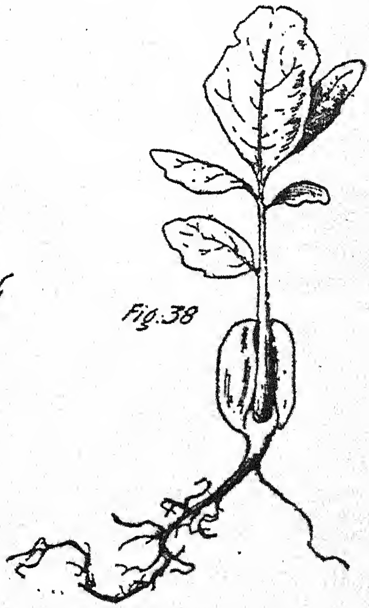


Fig. 38

The next one had been potted apex downwards. The plumule was only 2-inches high but carried five leaves ; while the radicle when extended was 6-inches in length and had a branch root ½-inch below the seed.

In this instance the plumule issued from the base of the seed and at the point of its junction with the radicle was brown in colour and was received into the *white* collar thus :

which is rather suggestive of a synapse. In that case,

the plumule having a protective membranous coating of the sarcolemma variety and the radicle and seed being now negatively charged, a positive charge would be communicated to the plumule to stimulate upward growth; the arrangement being, like the resinous secretion of leaf buds, a temporary measure.

With the seed coat away and the seed opened up the collar was found to have increased in size and thickness; otherwise it resembled Figure 31.

The plumule from $\frac{1}{2}$-inch above soil was as green as the leaves but brown near its base.

And here, I think, one fact stands out prominently. When the seed is planted or potted with the apex pointing downwards the plumule is not compelled to curve upwards to the light, but owing to the seed splitting is able to grow upwards in a straight line and emerge at the base of the seed. This facility of movement does not, however, seem to extend to the radicle which, when the seed is planted apex upwards cannot issue from the base but is forced to emerge from the top and curve its way downwards.

Fig. 30

When the seed is planted in a horizontal position the manner of growth is illustrated by Figure 30.

Another note which should be taken is that although all these seeds were potted at the same time and under exactly the same conditions the size and vigour of the seedlings presented considerable variation. The reason, as I found by experiment, was that the embryo in them all had not undergone uniform development before they fell from the

tree; very boisterous winds had prevailed shortly before the seeds were picked and no doubt some of them were immature.

Following the last seedling was one with a plumule 4-inches above soil and 7½-inches from the collar but, strangely enough the radicle did not exceed 3-inches in length and bore just nominal root filaments. The seedling was vigorous and in all respects identical with Figure 37 except there was no decay of the seed substance; nor, so far as I could judge, no diminution in the size or firmness of the seed.

In the sketches hitherto made the two halves of the seed have been forced apart. Normally the seed opens in this way :—

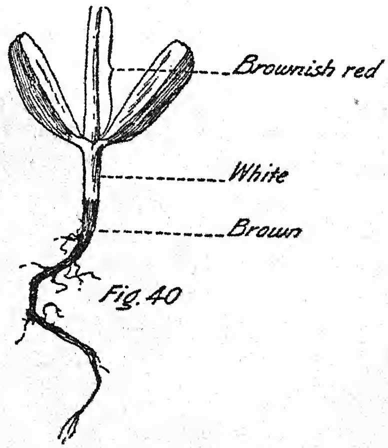
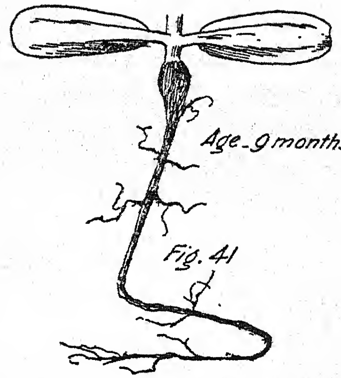


Fig. 40

In succession came a larger seedling, with six leaves. This was one of the horizontals. The plumule was 4½-inches above soil, and the radicle (single) 9-inches when straightened out. The seed coat had only split sufficiently to let the radicle squeeze through. Further examination disclosed the fact that what I have called the collar had extended in each half much farther into the seed substance and from it a swelling had occupied nearly the whole of the seed as far as the base.



Those two swellings are, I suppose, the cotyledons. If so, it is small wonder they do not leave the seed and we can understand how it is that some embryos occupy nearly the whole of the interior of the seed. The only thing that puzzles me is Why there are said to be *leaves !*

The seed was quite sound and somewhat narrower than when potted but this was probably due to the growth of the alleged cotyledons raising the surface of each half about 1/16th-inch.

An interval of a fortnight elapsed before another examination was made, and then it was of a seed potted apex downwards. The seedling, although 9½ months had intervened was quite small ; the plumule, although bearing seven leaves, being only 2/34ths-inch in height from the base of the seed, and the radicle (extended) less than 5-inches from the apex. Deprived of the seed coat the general appearance was almost identical with that of the last sketch, saving only that the seed substance was rather shrivelled and coloured red around the edges. That is to say what we have called swellings but which appear to be cotyledons were white, while the rest was red. The cotyledons, if they are cotyledons, were still more swollen and the collar more pronounced.

The seedling was quite healthy and particularly rich in chlorophyll. What I am pondering is why any part of the seed substance should be red, unless protection from short-wave lengths had been called for. The superabundance of chlorophyll is corroborative of this, but, on the other hand, how can we suppose one pot to be more subject to light-frequencies than another ? Unless, indeed, the soil had been disturbed and a path opened.

I had now only four pot-grown seedlings remaining and

took them week by week before touching those which were grown in the open ground.

The first of these was one potted apex upwards. The plumule was 4-inches above top of seed and carried four leaves, besides four young leaves. The radicle and plumule, at their junction, took a decided curve.

Fig. 42

The seed substance was not shrivelled like the last one but proved to be black and almost totally decayed. One half, however, showed that the collar instead of merging into a protuberance or swelling (*i.e.*, cotyledons) continued flat throughout the seed. The seedling was quite healthy and apparently required no further assistance from the seed.

The next one had had precisely nine months' growth. There were five leaves, covering $4\frac{1}{2}$-inches at the crown and rising 5-inches above the seed. The radicle when extended was 7-inches in length, was not single but threw out side roots from $\frac{5}{8}$-inch below the seed, thus :

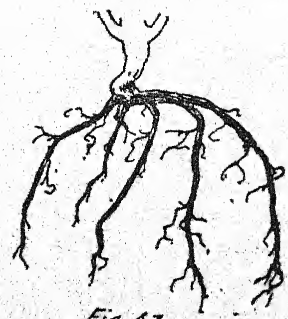
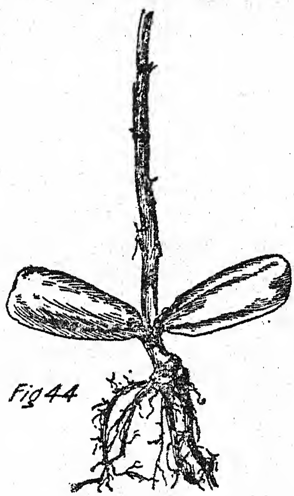


Fig. 43

There was no discoloration of the seed substance and no perceptible shrinkage; the slightly narrowed shape of the seed owing to the further growth of the cotyledons. The following sketch will show the growth to which I refer.



It is desirable to mention that all the potted seeds were *negatively* charged, because the soil in the pot took its charge from the positive air so that the polarity of the plant was reversed and I have said that plants grown under such conditions are not grown naturally. In the greenhouse they were, no doubt, cut off to some extent from vitalising air, and allowance must be made for that, but the doors and lights of the greenhouse were open when the weather permitted and the pots were placed in a position where they got ample light.

We may now compare those grown in the open ground with the pot seedlings.

Open Ground Seed.

I dug up one that had been sown horizontally. The root had descended too deeply to be got up in its entirety, so

that I could not determine the length of the radicle, but the seedling was unusually interesting from the fact that a plumule and radicle had *grown from each half of the seed*, while the seed itself had not suffered any diminution of size.

As will be seen from the drawings, each half of the seed had subdivided itself into two; the radicle and plumule being attached to a quarter instead of to half a seed, but in exactly the same way that I have previously described. The larger plumule bore nine leaves and the smaller, which was red in colour, leaf buds only. Although, measured from the upper surface of the seed, the first was only 4-inches in height, it exhibited a distinctly hard, woody and vigorous radicle and its seed substance was almost normal; that of the second being darker in hue. The following sketch is of the seedling before removal of the seed coat.

Fig. 45

To all appearance the above drawing would seem to be two seedlings growing from one seed but when the seed coat was dissected away the seedlings—not being in any way connected—fell apart, and were drawn in their relative positions.

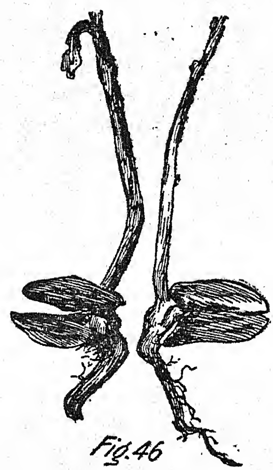
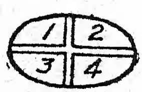


Fig. 46

The seedling on the left bore the nine leaves before mentioned. There was the same shrinkage of the seed substance, although not as much as the sketch suggests, and it was dark in colour. The seed on the right was normal in size and colour.

Here we have one of two things, *i.e.*, two plants from one seed, or two seeds in one seed coat. Probably it was what is known as a Phillipine.

Put together and then cut in transverse section the seed appeared as below :—



The bands or collar attached to each radicle and plumule issued from 1 and 2, and 3 and 4 respectively

The next seedling dug up—it was one of the horizontals—exhibited a single radicle and no fewer than six shoots, four of which carried leaves. After the modest behaviour of the seeds grown in the greenhouse this was a suggestion of riotous growth, and I wondered whether favourable position in a sunny South border where the soil was friable could be responsible for such luxurious growth, or whether seeds occasionally acted in that way.

I have not been able to find another and quite similar instance but daresay it is not particularly rare. Lord Avebury (on *Seedlings*) says that the seed of *Ardisia Japonica* presents the remarkable peculiarity of often containing several embryos, sometimes as many as six. The radicle in such a case points in various ways, and in germination each embryo makes its exit at a different place.

But that is not the same thing. If there had been several embryos in the acorn there would have been several radicles as well as shoots and several pairs of cotyledons. And as the latter occupy so much space in the seed, only miniature seedlings could have appeared. Shoots on the hypocotyl are met with now and again, as in the *Linaria Bipartita*, but that again is not quite on all fours with the specimen before us.

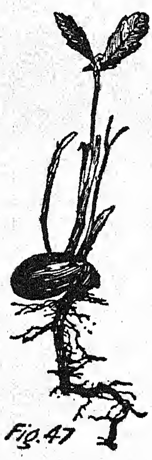


Fig. 47

It was first sketched with the seed coat intact.

It was not a case here of more than one seed within the seed coat as when the latter was taken off it was seen that the plumule and the shoots erected themselves from and were connected to the collar in quite the usual manner.

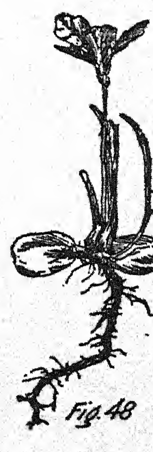


Fig. 48

Seen from the back the collar appeared to be broader and thicker than in the pot-grown seedlings and the radicle, both in length, thickness and hardness excelled that of any other plant yet examined, showing that root development was in keeping with upward growth.

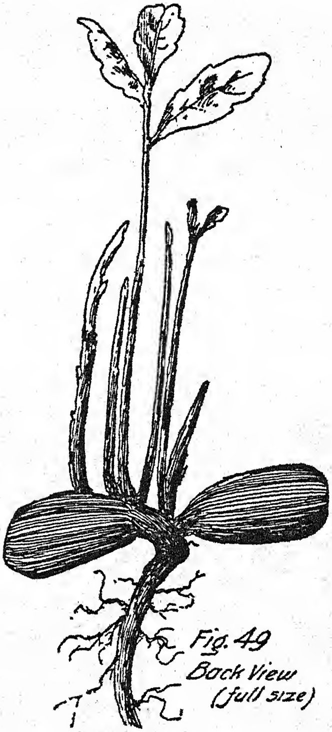


Fig. 49
Back View
(full size)

I also sketched it from the back.

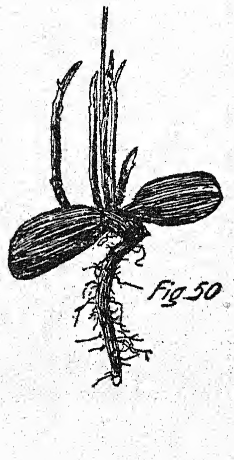


Fig. 50

I was much impressed by the fact that notwithstanding the superabundant growth there was no diminution of the seed substance.

Only one seedling now remained in the open ground and this also possessed features of interest. It was from a horizontally sown seed and was remarkable for vigour. The radicle (7-inches long) consisted of one main and several branch roots while the plumule rose 10-inches above the seed and carried fourteen leaves, the upper six of which were coloured russet brown. The age of the seedling was 9½ months.

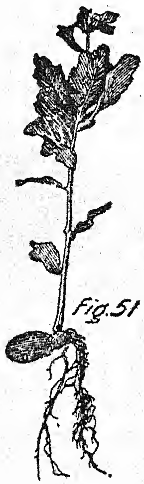


Fig. 51

It was then drawn to show the root development.

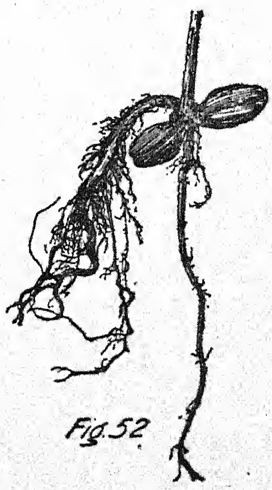


Fig. 52

It may be thought that the seed substance had shrivelled. This, however, was largely due to the fact that it was not drawn until twenty-four hours after it had been taken up and had lost moisture by evaporation.

The Electrical Structure of the Radicle.

We have seen that the radicle and the plumule are covered with a cuticle—that of the former being especially tough—and I have little doubt that these are insulating processes, similar to the sheaths of medullated nerves or the sarcolemma of voluntary muscular fibre.

Now the earth gives out negative current and we know that the roots, stem and venation of every tree and plant growing in the earth are negatively charged.

If the thick cuticle which covers the radicle provided effective insulation from the earth the charge communicated to the root would, of necessity, be an induced one and would therefore be of positive sign. As that does not obtain the charge must be direct, and there is no want of evidence that it is so.

Careful examination will reveal the fact that some, if not all of the lower root filaments are bare of this cuticle at their tips, which are white instead of the brown of the radicle itself. In the very young seedlings, before root filaments are formed, the tip of the radicle itself is bare and in that way current is picked up, or at all events it is in that way that the circuit is completed.

When the skin is stripped from the plumule the latter presents a smooth, even appearance but the radicle exhibits fibres which connect electrically with the root filaments. There is indeed a resemblance to the junction of animal nerve-fibres with the sarcomeres of voluntary muscle. Calling the cuticle the sarcolemma, the root filaments penetrate it and join up with the root fibres. The root filaments, in fact, convey current through an insulating process to certain conductors inside the radicle.

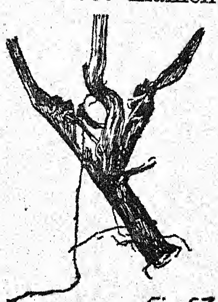


Fig. 53

The above sketch is of a portion of the plumule and radicle.

The upper 25 per cent. is plumule and the lower 75 per cent. radicle. Some of the fibres of the latter are seen, and on the left is a root filament which has pierced the cuticle, which, partly stripped, is pinned on either side of the radicle and plumule.

To afford evidence of what I have said about the extremities of the root filaments being bare of cuticle to enable them to pick up current from the earth I sketched a fairly well developed root.

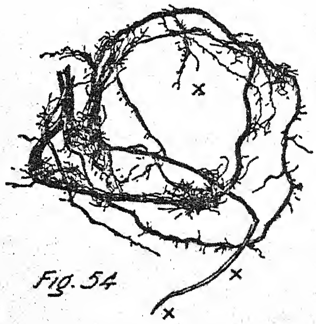


Fig. 54

The parts marked X are bare of cuticle and the lower end of the radicle itself was also bare for 2-inches.

Pot-Grown Seedlings (Continued).

I did not think there was much to be gained by further observation of the pot-grown seedlings but as three were still in the greenhouse, thought it as well not to waste them and accordingly took one from its pot and washed it.

It was one of those potted horizontally. The plumule was 6-inches above the seed and had put forth a second crown of leaves, making seven leaves in all. The radicle (extended) was $11\frac{1}{2}$-inches in length, and forked; its bare end, together with the tips of many of the filaments being very noticeable.

Just twelve months from the time of potting I examined this seedling again. There was some little additional upward growth and of course greater root-development. The radicle at its junction with the plumule was $\frac{1}{4}$-inch thick and its total length over 17-inches, with several branches.

The seed coat was entire and it was sketched before dissection.

From the lower drawing it will be noticed that the seed is discoloured but only slightly diminished in size and still firmly adherent to the plant. The Collar, or the stalks of the cotyledons, by which it is attached can be seen.

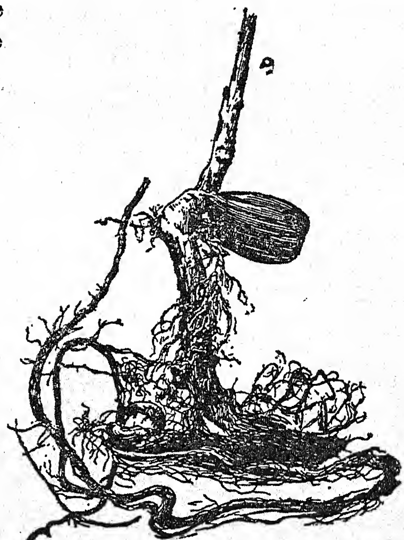


Fig. 55

A conclusion that one is entitled to come to from the large root development and comparative cessation of upward growth is, I think, that root room and upward growth are linked together. The roots, no matter to what extent they grow, cannot gather sufficient nutriment, sufficient electrical energy from the soil in the small pot to enable them to supply the needs of the growing plant.

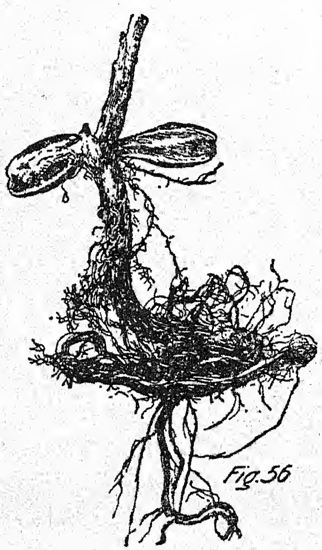


Fig. 56

The Oak, as we learned long ago, pushes its roots very deeply into the ground and its branch roots, with their filaments, probably cover a not inconsiderable area; pointing to the necessity for a large supply of current.

CHAPTER V.

HAZEL NUTS

Germination and the Seedlings.

HAZEL Nuts have so many features in common with Acorns that a detailed account of the seedlings would seem to be unnecessary.

In one respect, however, this seed differs from the Acorn, it does not split into two halves, unless under pressure.

The first sign of germination, *i.e.*, the early protrusion of the radicle, presented, when the seed was cut in longitudinal section, the following appearance.

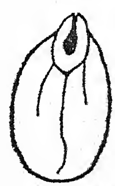


Fig. 57.

The dark part is the radicle, the oval nearly surrounding it the collar, while more of the space within seems to be filled by the cotyledons than was the case with the Acorn. Here also the cotyledons never leave the seed.

The first seedling examined was after a period of seven months, from the time of potting, had elapsed. The seed had been potted in a horizontal position and the plant had much the same aspect as that of a young oak of similar development, except that the plumule was sturdier and the radicle thinner and not quite so long. The leaves were bright with chlorophyll but from a point immediately below them and extending to within $\frac{3}{4}$-inch of the seed the plumule was red in colour and from that, I argue, of delicate constitution. Further leaves were in course of formation and the buds were borne on stalks, whereas in the Acorn they sit closer to the stem.

The seedling was washed clear of soil and sketched.

There was merely a split in the seed-coat to accommodate the collar and it is worthy of observation that this protrudes farther from the seed than the collar of the Acorn; the radicle and plumule being rather more than 1/16th-inch from the seed; those of the Acorn are always close up.

Cut in section along the line of the split in the seed coat it was seen that the collar was not adherent to both halves—as in the Acorn—but emerged whole from the apex of the seed.

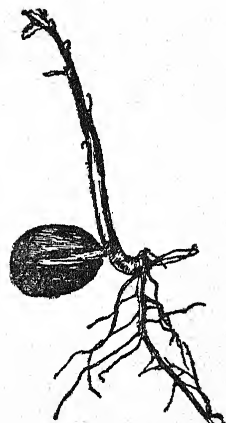


Fig. 58

The following is a sketch of the seedling, and seed cut *in section :*

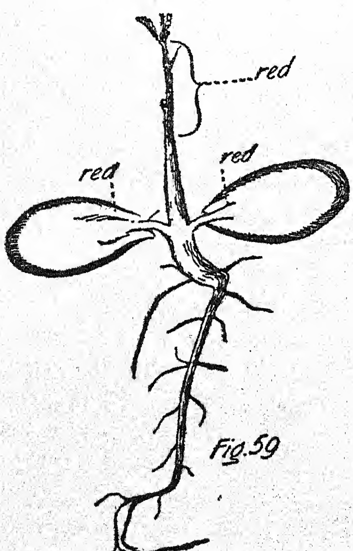


Fig. 59

At the Meeting of The British Association at Bournemouth in September, 1919, I found occasion to mention the want of uniformity in germination and growth common to all seeds and expressed the opinion that it was due to inequality in the matter of development of the embryo at the time of sowing; instancing trials of Hazel Nuts which although potted on the same day varied as long as several months in germination.

It so happens that I sketched two of them and they exhibited a marked difference.

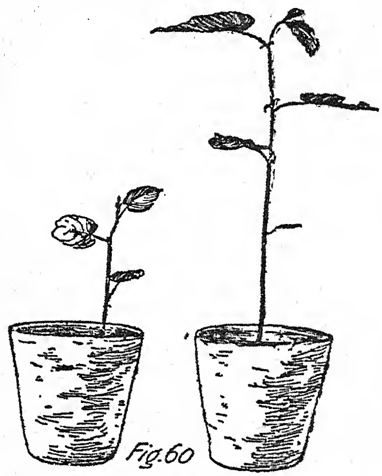


Fig. 60

Both the specimens were 7½ months old; respective heights above soil, 3-inches and 8-inches.

Taken from the pots and washed, to ascertain the root development they appeared as below:

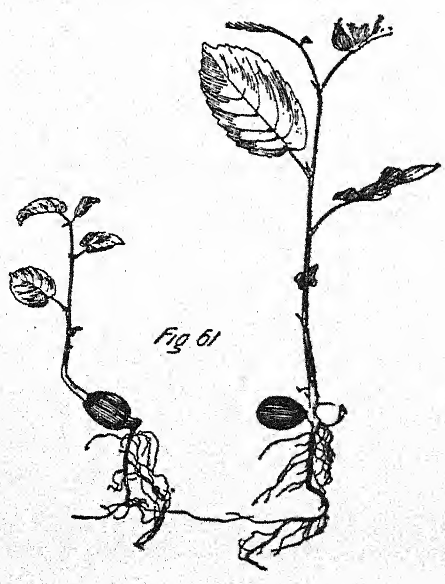


Fig. 61

Both these seeds were potted under exactly similar conditions and the pots placed side by side in front of one of the windows in a cool greenhouse. They therefore received plenty of air and of light—during the last two months, of sunlight. Notwithstanding this there was a total absence of discolouration of the green of the chlorophyll, inclining one rather to the belief that the seedling of the Hazel is of more vigorous constitution than the seedling of the Oak.

In the plant on the left the plumule, owing probably to some obstruction in the pot, had curved behind the seed so that an allowance of about $\frac{3}{4}$-inch in height should be made.

Further examination of the smaller seedling disclosed the fact that the seed as well as the seed coat had split and after the latter had been taken off the seed was gently opened out—from its base—and sketched.

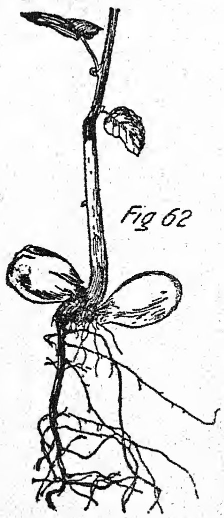


Fig 62

The collar can be seen distinctly in this and the next drawing and it will also be noticed that there is no apparent shrinkage of the seed substance.

For purposes of comparison the larger seedling was treated in the same way, but in this instance the seed had

not split; nor do the Hazel Nuts often do so as their formation is not quite the same as that of the Acorn.

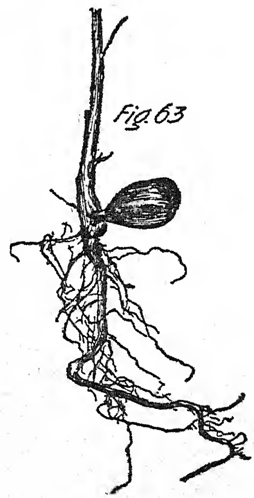


Fig. 63

Although all the seeds were potted on the same day two of them were only now showing their first leaves above soil. One of these I had re-potted in a larger pot a week before as it was desired to make a comparison between the two in the matter of root development—given more room—and upward growth.

One month later the seedling in the larger pot had put out a second stem, 1½-inches high and with four leaves. Both plants were about the same height. This on the 16th August.

On September 16th, I shifted both seedlings into larger pots and examined the one with the second stem, noting the following details:

Age: 11 months and 8 days.
Height of main stem: 5¼-inches.
Height of secondary stem: 2¼-inches.
Spread of leaves: 7-inches.
Number of leaves: 10.
Number of buds: 9.

The root development was very profuse and the extremities of the filaments were bare of cuticle. The seed had split and it having been potted horizontally it was seen that the upper half had diminished in size and had lost most of its membrane, while the lower half was as fresh and as large as when the seed was potted. The radicle had curled over the seed before descending—owing, no doubt, to some obstruction. It was then drawn.

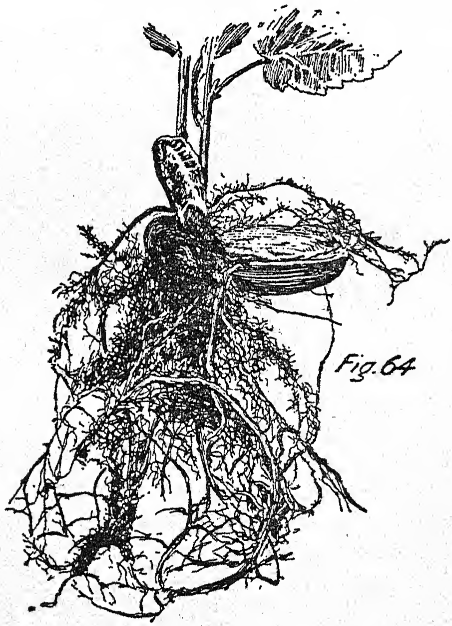


Fig. 64

The main stem (plumule) is on the left in the sketch, and the upper half of the seed exhibits the swelling which was so noticeable in the Acorn and which, I suppose, is a cotyledon.

Further experiments might have been productive of interest. Both with the Acorn and the Hazel Nut it has, I think, been made quite clear that growth, as well as flow of current, is along the line of least resistance. Something or other, however, intervened and I was unable to observe the further progress of these seedlings.

CHAPTER VI.

HORSE-CHESTNUTS

Germination and the Seedlings

WE may now be supposed to have potted the "Conker" described in Chapter II., under conditions favourable to germination. If, however, we had been able to dissect it beforehand we should have noticed a knob-shaped piece inside much like the end of a dumb-bell.

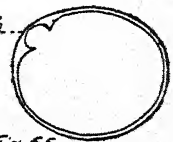


Fig. 65

In this knob, so far as I could see, the embryo radicle and plumule and the attachment of the cotyledons appeared to be esconced. It is difficult to even guess at the shape and presentment of the latter, as, with those of the Acorn, the Hazel Nut and the Walnut which never leave the seed or the shell they live out their life underground. It would seem, however, that their shape is similar to that of the seed and that they lie close to its sides for the reason that at a certain stage of development the middle part invariably falls out if the seed is cut in section.

The first seed was sown in a pot on the 8th of October and showed its first leaves above soil on the 8th of April; an interval of just six months.

It is a red letter day in the history of the seedling because it for the first time commenced an independent existence as a *plant*.

The following is a sketch of it:

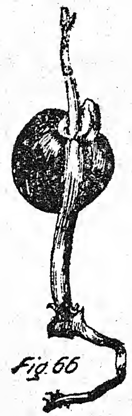


Fig. 66

The plumule near its junction with the radicle was red—probably because the seed had been near the surface of the soil and required to be protected from actinic rays—while the upper part was bright with chlorophyll.

Note will be taken that what I called the collar of the Acorn and Hazel Nut assumes here the form of a cup in which the plumule sits. Later on it will be seen that this is a continuation of the tough membrane covering the radicle, connecting directly with the cotyledons within the seed.

With growth, rupture of the seed coat is, of course, inevitable, and the insulating processes, the fibroid layer and the inner membrane, meeting with the same fate, the Leyden jar formation is broken up. All parts of the plant other than, possibly the plumule, and certainly the leaf buds, are now negatively electrified and there can be little doubt that the cotyledons have a useful function in storing if not in collecting current before sufficient root filaments are formed to pick it up in quantity. There is also the question whether during the earlier days of the seedling there is not a synaptic junction between the posterior part of the plumule and the interior part of the radicle. Both are covered by a tough membrane and if such a synapse existed the plumule would be positively charged and therefore

the leaf buds. After the first leaves had emerged above soil and could take in the air charge the usefulness of such a synapse would disappear and the plumule would be functionally as well as anatomically continuous with the root. It is not easy with very young seedlings to get accurate galvanometric tests but when I have, as I believe, got a reliable reading the plumule exhibited a positive reaction, whereas in an older plant it is always negative.

It has been impressed upon me so frequently that the seed contains nutriment for the sustenance of the seedling that I have expected to find constant shrinkage of the seed substance as growth proceeded. Very many experiments have been made but I have not seen any evidence of such shrinkage.

The seedling shown in the last drawing was washed free of soil, cut in section and the plumule shortened.

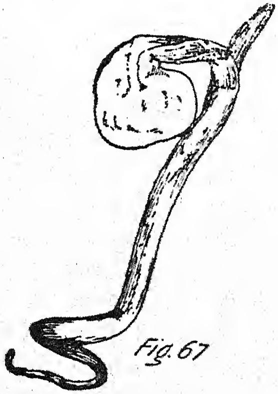


Fig. 67

The sketch is taken nearer the plant than the last but is of the same seedling.

Growth had taken place from the knob and the connection was from the *sides* and not from the centre of the seed as in the case of the Acorn and Hazel Nut.

I am giving the ages of these seedlings but the relative progress made by them depends not so much on the factor of time as upon the condition of the seed when sown. Some seeds are more advanced, more mature than others, and therefore make better headway.

On April 13th another having shown above soil it was sketched first in the pot, as it was about to put forth its second leaves :

Fig. 68

and then after it had been washed and the seed cut in section.

Fig. 69

The radicle emerged from the seed just above and on the *left* of the circular lighter patch, whereas in the last example it was on the *right*, but in a symmetrical position. From its junction with the radicle the plumule to half its height was pink in colour, merging in the upper part into chlorophyll. The membrane, or skin, coating the radicle

extended into the seed substance and seemed to provide protection if not additional insulation to the plumule. Tested galvanometrically, however, the only part distinctly positive was the foliage, the rest being of negative sign; I am adhering to the natural polarity.

Where the plumule issued from the seed it was tongue-like and the collar continuous with the radicle, the former being seated in a species of cup, the sides of which connected with the root, thus:

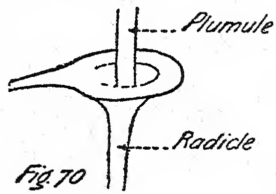


Fig. 70

and when cut in section:

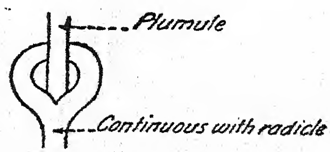


Fig. 71

and further:

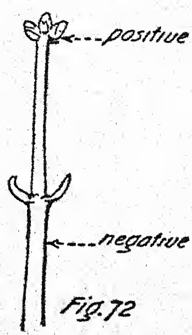
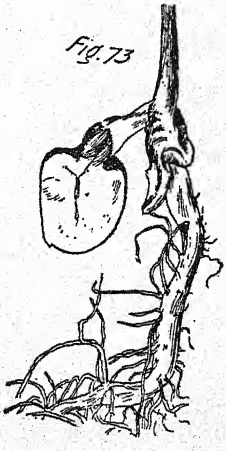


Fig. 72

Notwithstanding the fact that speculative reasoning very frequently leads nowhere there is great temptation to indulge in it. The following is pure theory:

It may be that the purpose and function of the membranous coatings of the radicle and plumule and the peculiar junction of the two have some connection with electrical supply. Before the rupture of the inner membrane of the seed in open ground growth the seed substance is positively electrified by induction. When by reason of the rupture of the inner membrane the seed substance is placed in direct contact with the soil it must become negatively electrified and without any provision being made to conserve a difference of polarity the whole seedling would be negatively charged; the stomata as yet not being able to take in charge from the positive air; although the leaf buds might, as a matter of possibility, obtain oxygen from the soil and so establish a circuit. But it is not altogether improbable that the membranes of the radicle and plumule interpose as effective a resistance as did the inner membrane while it was intact—until, at all events, the leaves could unfold and take in air charge. In such case the electrical condition would be for a time unchanged, but when the plumule with its crown of leaves gained access to the air the inductive process would no longer be necessary and the seed substance would, so far as its electrical function is concerned, merely serve to assist in collecting or in storing earth-energy.

In the first sketch of this series only the first leaves have developed and the radicle is destitute of root filaments; the two being, presumably, balanced. When, however, the second leaves are formed further root development is required to keep pace with upward growth and in order to preserve electrical equilibrium.



The accompanying figure shows the last example with the seed cut in section:

Half of the collar is hanging loose but the other half can be seen issuing from the dumb-bell like knob to which I have referred.

The next seedling was seven and a half months old, its second leaves were well developed: height above soil, ten inches; spread of leaves, fifteen inches. I sketched it before removal from the pot;

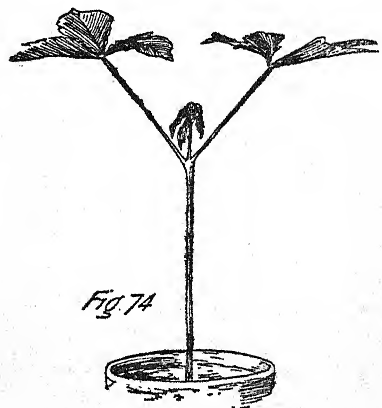


Fig. 74

And again when it had been washed free of soil:

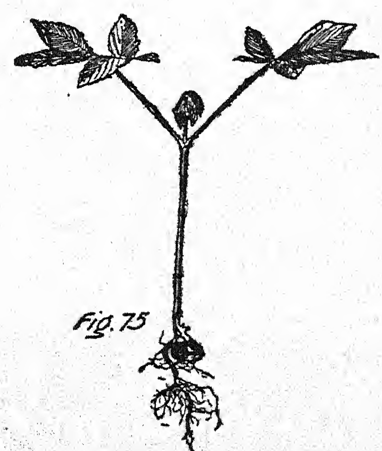


Fig. 75

One can hardly judge from it whether the seed had been drawn upon for nutriment, but the next drawing—which gives a good view of the collar—does not suggest it.

There was no sign of shrinkage that I could see. Nor does a close examination of its internal economy lend colour to botanical opinion, though I do not pretend to question it.

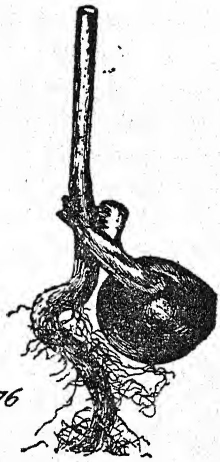


Fig. 76

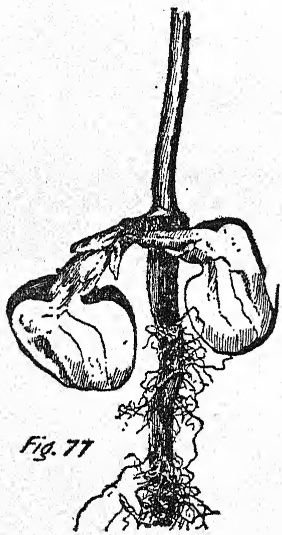


Fig. 77

The development exhibited in Figures 76 and 77 is deserving of attention. The collar is well defined and springs from the seed substance at a point just above the round lighter disc, which point identifies itself with the dumb-bell like protuberance always to be seen in this seed when it is cut in section. Furthermore, we now see that while the growth has been outward, an inward change has taken place; the wings of the collar extending around the sides of the seed. In the centre of the seed was a loose piece which is shown in the accompanying Figure: but which, as it fell out upon being handled, is probably not concerned with growth. When it did so the seed appeared as follows:

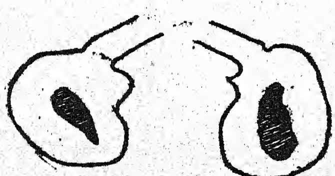


Fig. 78

So that it would seem that the outgrowth was from the sides of the seed only.

From the firmness and appearance of the seed and my recollection of it when it was potted I am of opinion that no portion of its substance had been used by the seedling for food.

Although the Horse Chestnut tree has taken very kindly to our climate and is common to the great majority of our gardens it is only, I am told, some three centuries ago that it was introduced into Europe. Apart from the erect racemes of attractive red and white flowers which beautify the suburbs of London, the timber is useful. The bark contains an astringent principle which is sometimes used in medicine and there is colouring matter in the outer membrane of the seeds which is of some value for dyeing purposes.

The seeds also contain a considerable quantity of starch, an oil said to be a remarkable remedy for rheumatism, and a saponaceous substance which, when reduced to powder, may be used for washing. They are also liked as food by horses, cattle and pigs.

CHAPTER VII.

SOIL AND WATER ELECTRICALLY CONSIDERED

Soil

QUITE apart from the chemical character of the soil—and therefore the question of suitable manures—its permeability to water and oxygen and from soil bacteriology we must, in my opinion pay equal attention to its electrical conductivity.

I am indebted to Dr. Russell's admirable work, *Soil Conditions and Plant Growth*, for much interesting information.

Pan Formation. "A pan is a layer of hard impermeable rock that gradually forms at the usual water level below the surface of the soil under certain conditions. Its effect is to cut off the soil above from the material below and therefore to modify profoundly the movements of water and air, leading often to swamp conditions. The effect on vegetation becomes so marked that in agricultural practice the pan has usually to be removed, often at considerable trouble and expense. . . . Pans are best seen when the sand is overlain by a deposit of peat. The sand is then bleached to a depth of 5 to 60 cms. Suddenly there comes a change: a coloured layer of solid rock occurs which may vary in colour from yellow to black and in thickness from 10 to 60 cms. . . . This is the pan: underneath it lies the sand proper. . . . But pans are by no means confined to peat: they often occur in forests, on heaths and on certain cultivated soils." . . .

"No method of cultivating these soils has ever been devised, and most of them still remain barren wastes, defying all attempts at reclamation." . . . "The bad effect of a layer of impermeable material near the surface is shown by the Loddington soil . . . typical of an area near

Maidstone, much of which was waste land. Its sterility was due to no fault in the soil, which is obviously of excellent type, but to a thin layer of rock lying near the surface. When this was removed a very good soil was obtained. The Harting soil, on the Upper Greensand, in West Sussex; the rock comes close to the surface, restricting both the root range of the plant and the water supply where it lies horizontally, but proving much less harmful where it dips at any considerable angle . . . The Dicker soil . . . is far from being hopeless, but it unfortunately lies on a deep bed of stiff clay which keeps it wet in winter and parched in summer. . . . Over-drainage is illustrated by the Shopwyke soil . . . it is spoiled by lying on a deep bed of gravel only nine inches or a foot below the surface. . . . Consequently it dries out badly in summer and does not repay much expenditure in the way of manures."

Let us study these problems with a view to seeing how far electrical conditions may enter into them, for if I have, as I claim, discovered a fundamental truth, electricity must, of necessity, be concerned in the matter. First we will have a few brief facts for our guidance:

(1) Dry soil is non-conductive of electricity.

(2) Water is mainly required as an electrolyte.

(3) Other things being equal soil conductivity rises and falls with rise and fall of temperature.

In the case of the pan first mentioned, swamp conditions would, of course, involve drainage, but the effect of such a formation would not only be to modify profoundly the movements of water and air but also that of the earth current.

Now, while water is essential as an electrolyte it is not an electrolyte of low resistance and it is to be feared that vegetation would fare badly if soil conductivity depended on moisture alone, for current in sufficient quantity is required to be constantly supplied to the roots.

In much the same way that the path of lightning from cloud to earth is governed by the distribution of electrolytes in the air so the direction or directions taken by earth currents must be subject to the distribution of electrolytes in the soil

and their quantity be in the inverse ratio to the resistance of the path or paths. It follows, therefore, that if every portion of the soil—or those depths which are reached by the roots of plants—is to receive the same current supply it must not only have exactly the same conductivity but must not be shut off by a fault, or break of continuity, such as those described by Dr. Russell.

We may be sure, quite sure, that in the absence of manure or fertilisers, electrolytes are neither equally distributed throughout the soil nor of uniform resistance, so that electrification of the soil cannot be everywhere the same. When a "fault" of the nature we have been discussing occurs the pocket, so to speak, of soil would, presumably, be cut off from the earth supply, or alternatively receive a diminished supply owing to the resistance of the rock, and be mainly dependent upon the atmosphere for its charge. This, with a dry upper stratum would, in the absence of rain, be negligible. It would appear, therefore, to be desirable to test soils both for E.M.F. and sign of current —to determine the nature of the charge—and where there is a deficiency to arrange for a constant supply at a voltage not materially higher than that of the earth.

When the underlying rock is at a depth permitting of root expansion a simple remedy might be to drive a metal rod or tube through it to enable the earth current to pass.

The Dicker soil lies on a deep bed of stiff clay. It is wet in winter, when cold renders the soil practically non-conductive, and parched in summer when dryness has an even worse effect; while in the case of the Shopwyke soil the conditions repeat themselves, dry soil prevailing during the summer months.

From an electrical standpoint too much importance cannot be attached to temperature, within certain limits, in its relation to soil conditions. In warm damp weather conductivity is at its maximum. Cold increases resistance especially of liquid and semi-liquid conductors enormously, and consequently lowers the quantity of current supply, not only to the roots but in its circulation through the vegetable organism.

With the advent of late Autumn, plant growth, as a whole is checked and there are very few plants which when tested galvanometrically at that season do not yield subnormal deflections.

Were we discussing a problem affecting animal organisms one could reasonably attribute the phenomena to a deficiency of nerve energy. If we apply the same reasoning to plant life we must, I think, assume that at such times the earth is not giving out the same quantity of current—possibly not receiving it—as it does during late Spring, Summer and early Autumn. What is called "forcing" is, after all, little more than a successful attempt to reproduce conditions favourable to growth but although a rise of temperature acts as a stimulant in lowering the internal resistance of the plant and of the electrolytes in the soil it has been shown by Dr. Russell and others that such rise must be kept within narrow limits, not only because protoplasm is unable to do more than a certain amount of work but for other reasons. Dr. Russell says: "A slight temperature increase producing a marked increase of growth; above a certain temperature (which varies somewhat with the conditions the rate of growth falls off; at higher temperatures the plant suffers, the various processes no longer work harmoniously, the protoplasm loses efficiency till finally the plant dies.

"For purposes of crop production the temperature range is limited by certain secondary effects. If the temperature is too low a purplish pigment appears on the leaf, and the plant grows so very slowly that it is liable in its early stages to succumb to insect pests . . . and in its later stages to be cut down by Autumn frosts before it has had time to ripen" (low electro-vitality; "if, on the other hand, the temperature is too high, the plant becomes taller than usual, less robust and, when much water is also supplied, liable to all the fungoid pests that give so much trouble in commercial greenhouses. Only over a comparatively restricted range of temperature is it possible to obtain the compact sturdy habit aimed at by the grower."

That is a very striking endorsement of what I have said about the effect of the sign and quantity of current. The terms positive and negative are misnomers and only serve a useful purpose in indicating the direction of energy and movement. I have shown that an excess of current is harmful to the plant and that an upward driving force, *i.e.*, positive to bottom and negative to top of soil produces tall, anæmic growth. Now positive to bottom and negative to top of soil simply means that the current takes an upward direction. If the *soil* and the plant in it were unduly stimulated whether by heat, further assisted by water, reducing resistance to a fraction of that which normally obtains, or by high electrification equilibrium would be disturbed, by the energy from below being made greater proportionately than the energy from above, and there would be an *upward* driving force as an inevitable consequence. The effect of abnormal temperature appears to be fully recognised but the views held in regard to certain other forms of stimuli are inconsistent and are at variance with experimental results. Moderate increases of temperature must not be exceeded, but high tension currents are persistently employed in electro-culture, even under the direction of men of such undoubted scientific attainment as Sir Oliver Lodge. It is very much on all fours with the application of high tension currents to the human body, and just as empirical.

University of All'd.

Water

Dr. Russell tells us that "the relationship between food supply and water requirements is very interesting but not easily explained," and that "unfortunately no correlation has been traced between water requirements and plant structure."

I am not concerned with the chemical side of the question—that is in very able hands—but with water as an electrolyte.

"The amount of water in the soil has a marked effect on the character of the plant, the time of ripening, and the composition of the grain. As the water supply increases,

so the extent of the leaf surface increases; while a diminished water supply is met by a smaller leaf surface, admitting of less transpiration."

And also of a lower air intake.

"Thus on moist soils—clays and loams—the plants usually have large wide leaves and grow to a considerable size, whilst on the drier sands the vegetation is narrow leaved and more stunted."

Due, in some measure at least, to lowered current supply.

"A copious water supply leads to a more protracted growth and to a retardation of the ripening process; indeed, in very wet districts grain crops are grown only with difficulty if at all, because ripening may be so long delayed that frosts supervene and damage the crops."

Now copious water supply counterfeits electrical stimulus by reducing soil resistance to the minimum permitted by temperature and encourages the plants to continued growth. I have mentioned elsewhere (*p.* 54) that under electrical stimulus I had some Mustard Plants over four feet high, but the seeds were few in number and very late. More water is needed during the period of active growth than during germination or ripening, but, as Dr. Russell observes, "much more work is required from the physiological side before definite rules can be laid down."

We know, however, that in countries such as Egypt and India, where higher temperatures prevail some plants require a great deal of water, the supply of which is sometimes a matter of considerable difficulty. Cotton needs, I believe, about thirty inches, and Rice not less than eighteen. If I can show that some part of this supply can be dispensed with it will not be without a practical bearing upon horticulture and agriculture.

Some years ago I carried out a series of experiments with ferrous sulphate as an electrolyte and gave an account of one or two of them in *Electro-Pathology* and *Studies in Electro-Physiology*. Since then other experiments have been made, and as they confirmed the results previously obtained, some mention of them may be useful at this juncture.

I wanted to get an idea of the quantity of water needed for growth as compared with the quantity necessary to give conductivity and capacity to the soil of a pot plant. Dry soil has no capacity and is of the nature of a dielectric, so that if it is to remain dry other means must be taken to administer to the requirements of the plant.

I took, sifted and weighed a certain amount of soil. This I divided into two equal portions and placed them in a gas oven until every particle of moisture had been expelled. One of these moieties was then saturated with a solution of two per cent. of ferrous sulphate and replaced in the oven until complete evaporation had again taken place; call these soils A and B.

I then selected two roots of grass, of the same size and species, and potted them, one in Soil A and the other in soil B, containing the ferrous sulphate; electrifying the latter by means of a dry cell of 1.5 volts. Both pots were then placed in a cool greenhouse, in a good light and in a position where no moisture could reach them. This on August 3rd, 1918.

The following are extracts from my notebook:

"Each root was slightly moist. Weight of each, ½-oz. when washed clear of soil; blades cut to 2-inches. Greenhouse very dry. Light good, with ample sun.

"August 12th: Blades of both withering. Gave 1-oz. of water to each, and propose to continue this daily.

"August 14th: B showing signs of life, but not A.

"August 24th: B throwing out fresh shoots.

"August 25th: A is showing three small green blades; B has more than twenty. Stopping all water.

"September 7th: A still survives but is withering; B has a good display with blades 4¾-inches high. Neither have had any water since August 25th.

"September 14th: A seemingly dead; B flourishing, with blades 5½-inches high, whereas those of A never exceeded 2-inches.

"September 19th: B still vigorous *but growth not maintained.*

"OCTOBER 10TH: B still vigorous but growth at a standstill, as might be expected.

"DECEMBER 17TH: Tallest blade of B, $5\frac{1}{2}$-inches; second, 4-inches. Vigour slightly fallen off but this may be due to cold weather; A shown no sign of life since September 14th."

Here, I submit, is evidence that given a suitable electrolyte in and same measure of electrification of the soil a plant would probably thrive upon a mere fraction of the water ordinarily required. We must, of course, make allowance for evaporation from a pot and take into consideration the limitation of root depth, but the conditions were the same for both A and B.

In one respect the experiments were unsatisfactory. I should have interposed a resistance in the circuit of B to reduce the current strength nearly to that of the earth. As it was B was over-stimulated.

CHAPTER VIII.

TESTING IN VACUO

I DEVISED an apparatus some years ago, and made brief mention of it in *Electro-Pathology*, for the purpose of putting to the test certain theories I held of the origin of currents exhibited by animal and vegetable skins, mucous membranes and excised matter generally. Owing, however, to causes into which I need not enter the apparatus was not constructed until the year 1916. The following is a photograph of it:

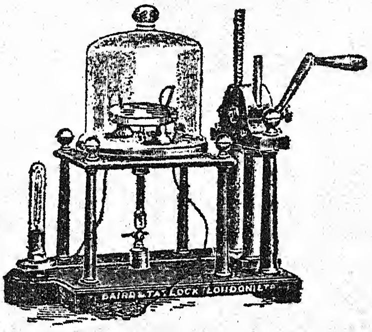


FIG. 79—APPARATUS FOR TESTING IN VACUO.

The air-pump was a double-acting one. The table shown above the bedplate consisted of a disc of cork, $4\frac{1}{4}$-inches in diameter, dried in an oven, boiled in paraffin wax, and affixed by means of Chatterton's compound upon cork supports which had been similarly treated, to the bedplate. Holes 1/10th-inch in diameter were drilled in the latter, to admit flexible wires, and made air-tight by the compound; to each of the wires where they terminated at the table a steel needle was carefully soldered.

The connections are shown in Figure 80.

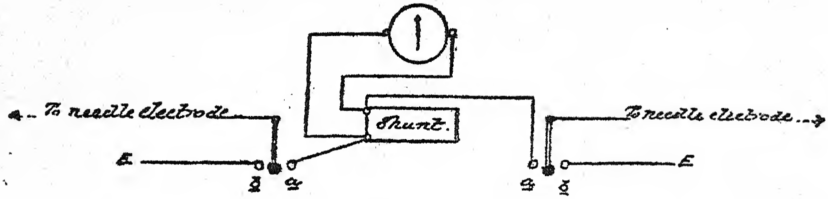


Fig. 80

To test in air, *i.e.*, with the bell jar removed, both switches were put over to contacts *a*, *a*, while to " earth " the object under examination it was only necessary to move both switch levers to contacts *b*, *b*. The shunt enabled the full deflection to be calculated when it was thought desirable to do so.

There was, from time to time, a good deal of trouble with this more or less makeshift apparatus. The pump did not give a very effective vacuum unless it was kept going and the mercury gauge did not register, so that, unfortunately, I am not able to give the number of inches of vacuum.

It, however, yielded some extremely interesting results but before describing them it will be as well to go into the object with which the experiments were carried out, their bearing upon electro-physiological research, and their possible biological significance.

In my view, the currents observed from animal and vegetable skins, from mucous membranes and excised muscle and nerve, as well as from vegetables and fruits taken from their natural environment, are due to air charge ; that is to say, they are charged by an external source or vehicle of energy which may be air of normal sign and potential, or air with its sign and potential altered by energy emanating from animal bodies.

Dr. Waller,* however, is of different opinion. To make quite sure of that opinion I shall have to quote him at some length :

******Signs of Life*.

"I have been asked," he said, "why I chose to designate the effects by the name of 'blaze-currents' rather than 'positive polarisation currents,' or 'post-anodic action currents.' I think you will readily understand the answer to the negative parts of this question. Apart from the fact that the name 'positive polarisation,' . . . has been adversely criticised by Hermann and Hering—shown by them, indeed, to be a misnomer, inasmuch as the effects to which it was applied are demonstrably due to post-anodic action current—I think it is sufficient to refer to the equivocal or antidrome blaze as forbidding the use of the term, 'positive polarisation.' The use of the term 'post-anodic action currents' you have just seen to be altogether unjustified for these skin currents; in one case the current is not post-anodic at all, and in the other it is post-anodic, but of opposite electrical sign to that of a post-anodic state. In muscle and in nerve a post-anodic spot is galvanometrically negative; in the skin it is galvanometrically positive. So that both these cumbersome expressions are happily inapplicable, and a new term is required. I have been led to adopt the term 'blaze-current' and I think you may now understand how it arose in the study of retinal effects, and how it serves to clearly earmark a natural group of phenomena of a very definite physiological meaning.

"A 'blaze-current' is literally and strictly a 'current of action,' but it is a particular kind of action current, and requires a distinctive name. The known phenomenon to which it bears most resemblance is the discharge of an electrical organ, and we shall not infrequently find the term 'discharge,' a convenient indicative word. But as a distinctive and specific name, the word 'discharge' is insufficient, all the more so from the inconvenience that would arise when we have to refer to the 'blaze-currents' aroused by the condenser discharge.

"I have had another reason in my mind that has helped to make me use the expression, 'blaze-current.' The great mass of living things, whatever else they may give and take from their surroundings, take oxygen and give carbonic acid; they may live slowly or they may live quickly—

sluggishly smoulder or suddenly blaze. A muscle at rest is smouldering, a muscle in its contraction is blazing; the consumption of carbohydrate and the production of CO^2 never absolutely in abeyance, even in the most profound state of rest, are sharply intensified when the living machine puts forth its full power; and there is then a sudden burst of heat, and an electrical discharge, by reason of an electro-positive state of the active muscle giving birth to a current of action which, in effect, you may without great stretch of thought, regard as of the family of 'blaze-currents.' So that in last resort we find that these striking electrical effects in living matter that we had hardly considered electro-motive at all—in the eyeball, in its crystalline lens, in a bean or pea or leaf or flower—are, after all, intense local changes, significant of intense local action, that may be imagined and characterised as a blaze amid the smouldering state of living matter.

"There is a certain similarity between a 'blaze-current' and the discharge of an electrical organ—no very close and detailed resemblance indeed, yet one that cannot be ignored."

I propose to offer evidence to show that the currents mentioned by Dr. Waller have no such origin as that attributed to them, that they are simply manifestations of air-charge and that the so-called "blaze-currents" are nothing more than exhibitions of the electrostatic capacity of the objects or substances under examination.

First of all, however, we might see what Professor Bose has to say upon the subject, bearing in mind that as the potential and sign of the air-charge are liable to variation the response of capacity to that charge must also vary, so that it is the exception rather than the rule to find two sets of observers in agreement. Professor Bose says:* "I allude to the so-called 'blaze-current' of Dr. Waller. By this is meant an after-current in the same direction as the exciting current. . . . The intensity of this homodromous after-effect was thus dependent on the degree of vitality of the tissue under experiment. Hermann and

**Comparative Electro-Physiology.*

Hering, however, afterwards showed that what Du Bois-Reymond called 'positive polarisation' was in reality excitatory reaction. These excitatory effects are known to be caused by either the anode or the kathode; and I have . . . demonstrated the fact that it is the differential excitability of a tissue which determines such uni-directioned response. It is difficult, therefore, to see the necessity of a new name for these phenomena. Dr. Waller himself, however, offers the following explanation:

"The great mass of living things, whatever else they may give and take from their surroundings, take oxygen and give carbonic acid; they may live slowly or they may live quickly—sluggishly smoulder or suddenly blaze. A muscle at rest is smouldering: a muscle in its contraction is blazing; the consumption of carbohydrate and the production of CO^2, never absolutely in abeyance, even in the most profound state of rest, are sharply intensified when the living machine puts forth its full power, and there is then a sudden burst of heat, and an electrical discharge."

This amounts to another way of saying that the cause of the excitatory galvanometric effect is some explosive dissimilatory change, a view which I have already shown . . . to be quite untenable. I shall presently describe experiments which will further show that galvanometric responses, not to be distinguished from this, take place when *there is no possibility of any consumption of carbohydrates or production of* CO^2.

The fact, however, that the excitatory after-effects described disappear on the death of the tissue, has led Dr. Waller to put forward the generalisation that this so-called "blaze-current" is the final distinction between living and non-living matter. . . . Now, while it is certainly true that the domain of physiological phenomena has not yet been so thoroughly explored as that of the physical, it is nevertheless equally true that no one could venture to claim that even physical phenomena had up to the present time been exhaustively studied. It is, then, somewhat hazardous to declare that because a particular phenomenon has not been observed to occur in inorganic matter, it is

by that fact demonstrated to be hyper-physical in its nature, and must be relegated to the different and mystical category of the exclusively vitalistic. The very foundation of such a statement would be swept away from under it, the moment it was shown that the same phenomenon followed, under the same circumstances, in conditions which were admitted to be purely physical."

Professor Bose experimented with a lead strip and having obtained responsive after-effects from it went on to say: "Since we obtain similar electrical effects from the inorganic, it is clear that excitability is the property, not of the organic alone, but of all matter. . . . It is therefore unnecessary to call in the aid of such indeterminate factors as vitalism, or assimilation and dissimilation."

That is the kind of thing to which electro-physiology has accustomed us. Two scientists disagree and a third differs from both! In justice, however, to Professor Bose I must endorse the opinion that the phenomenon is a purely physical one.

The following experiments may serve to throw some further light upon the matter:—

For the first experiments laurel leaves were chosen, principally because they were sufficiently thick and tough to promise durable contacts, and were connected thus:

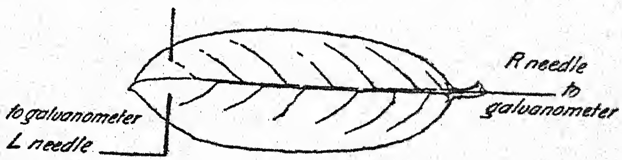


Fig. 81

EXPERIMENT No. 1.—The Deflection (D) was first taken in air, *i.e.*, with the bell jar removed. Galvanometer resistance, 12,000°.

D = Off Scale, negative.

The leaf was then switched to earth, the bell jar replaced and the air exhausted. After ten minutes D = 15 mm. negative.

Expectant of zero I was dissatisfied, regreased the bell jar and substituted another leaf.

Experiment No. 2: Much Smaller Leaf.—

D = (in air) 90 mm. negative. Earthed ten minutes in vacuo.

D = (in vacuo) 15 mm. negative, but upon further pumping fell to zero.

Experiment No. 3: R Needle in aerolæ, L Needle in stalk, *i.e.*, former connections reversed.

D = (in air) 90 mm. positive; steady. Ten minutes earthed in vacuo, when

D = (in vacuo) zero.

During the ensuing ten minutes no deflection was observed upon repeated disconnection and reconnection with the galvanometer. Everything was then left untouched until the next morning when D = Zero.

The bell jar was then taken off without touching the electrodes and the leaf exposed to air in the dull diffused light of the laboratory for one hour without any change taking place. The leaf was then placed in the open air—occasional sunshine—for half-an-hour, the Needles replaced as before and a fresh observation made.

D = (in air) 70 mm., but fell in five minutes to zero.

It was then given three hours' open-air exposure when

D (immediate) = 150 mm., but fell in five minutes to zero and thereafter gave no response.

Experiment No. 4: Apple cut in section, and wiped to prevent diffusion.

D = (in air) 190 mm. +.

After ten minutes earthed in vacuo, 500° shunt

D = (in vacuo) Zero.

Note: Went negative after a time, due to earth-current.

Experiment No. 5.—Laurel Leaf.

D = (in air) Off Scale.

After forty minutes earthed in vacuo

D = (in vacuo) Zero.

EXPERIMENT No. 6: LAUREL LEAF.

D = (in air) 170 mm.

After one minute earthed in vacuo

D = (in vacuo) Zero.

EXPERIMENT No. 7: LAUREL LEAF.

D = (in air) 170 mm. +.

After eight minutes earthed in vacuo

D = (in vacuo) Zero. In three minutes went to 40 mm. negative.

EXPERIMENT No. 8: HYDRANGEA LEAF.

D = (in air) 165 mm.

After twenty minutes earthed in vacuo

D = (in vacuo) Zero.

EXPERIMENT No. 9: HYDRANGEA LEAF.

D = (in air) 132 mm.

After fifteen minutes earthed in vacuo

D = (in vacuo) Zero.

EXPERIMENT No. 10: ONION. R Needle to root; L Needle to foliage end.

D = (in air) 2750 mm. negative (Full deflection, 500 ohm shunt).

After twenty-five minutes earthed in vacuo

D = (in vacuo) Zero.

Upon the face of them these experiments appeared to be quite conclusive and to prove, beyond any manner of doubt, that all the deflections were due to air-charge. But it was necessary to guard against the possibility of error, and error might be introduced by

1. Polarisation.
2. The Nature of the Contacts altering, and
3. Diffusion, with consequent neutralisation of charge.

There was also the question whether earthing in vacuo produced a different effect from earthing in air. To determine these points further experiments were carried out, with the following result :—

1. Polarisation of electrodes did not play any appreciable part in the phenomena, but
2. Differences of Contact did, probably owing to one

contact drying or partly drying up before the other was similarly affected.

3. If the object under examination (or the electrodes when they were in contact with it) were touched with the bare fingers the natural charge was interfered with, and for this reason
4. *Dry* rubber gloves should be worn throughout the tests and the utmost care exercised in keeping the gloves absolutely free from moisture.
5. If the above conditions are observed the object, whatever it may be, under examination loses its charge when earthed in vacuo much more quickly than it does when earthed in air, and
6. Some things, such as an Onion or an Apple, will not when earthed in air lose more than a fraction of their charge in several weeks or even months.

I cannot too strongly emphasize the importance of making firm contacts with the Needles and of avoiding the "shorting" which would result from diffusion and lead to false readings. Care should be taken in every instance in recording the immediate or initial deflection that there is not a quickly commencing fall as that is an indication either of charge from some external source of energy other than the air or of diffusion.

A very interesting experiment was with the same half of the apple mentioned in *Experiment No.* 4. After the deflection had remained subject to a weak and fluctuating negative earth-current for some little time it was disconnected and placed in the open air, in the sun, for three-quarters of an hour, to see if it would recover.

The Needles had been cleaned and were replaced in the same holes and switched to earth (in air) for forty-five minutes.

The full initial deflection was 3080 mm., and after the forty-five minutes earthing

D = 3080 mm., showing that it had not lost even one division of the Scale. It was then earthed for forty-five minutes in vacuo, when

D = 275 mm., with a very faulty vacuum.

It would not serve any useful purpose to give a detailed account of all the tests, but the following tabulated statement may be of interest :

SUBJECT.	Initial Deflection in Air.	Number of Minutes Earthed.	Resultant Deflection in Air.	Resultant Deflection in Vacuo.	REMARKS.
	mm.		*mm.*	*mm.*	
Laurel leaf -	90 neg.	10	...	0	
,, ,, -	90 pos.	10	...	0	
,, ,, -	182 neg.	10	140 neg.	...	
,, ,, -	105 pos.	10	85 pos.	...	
Cut Apple -	190 pos.	10	...	0	
,, ,, -	280 pos.	45	...	25 pos.	Different and larger Apple. Faulty vacuum.
,, ,, -	280 pos.	45	280 pos.	...	Same half as above.
Hydrangea leaf	165 pos.	20	...	0	
,, ,,	225 pos.	20	185 pos.	...	
,, ,,	132 neg.	15	...	0	
,, ,,	135 pos.	15	80 neg.	...	

The contacts were occasionally varied so as to change the polarity and where no figures are given in the fourth or fifth columns it may be taken to mean that the subject was earthed in air *or* in vacuo, as shown.

There is not in the above, I submit, nor was there in any other experiment, evidence of polarisation which need be considered. The third and fourth laurel leaves and two of the Hydrangea leaves exhibit some loss which might be attributed to polarisation were it not for the contradictory testimony of the cut Apple. The loss was, I believe, due to the changing character of one of the contacts but even if it be called polarisation it has no material bearing upon the experimental results, which go to show that the phenomena of so-called currents from animal and vegetable skin, etc., etc., have their origin in charge absorbed from the surrounding air.

As regards the occasional reversals of polarity observed by Dr. Waller and other writers it is, I think, only necessary to remark that the phenomenon is common enough when there is electrostatic capacity in the circuit and should sufficiently explain "blaze-currents" as being nothing more than a manifestation of purely physical phenomena.

At the time these tests were taken I was using a garden "earth." This will explain the negative variation which sometimes followed upon the fall to zero. And I should like to make it clear that such fall does not imply more than temporary exhaustion—suspended animation—; between which and electrical death there is a wide difference. Life in a seed or a plant—in an electro-physiological sense—is dependent upon the retention of its electrostatic capacity and this in turn depends upon the preservation of its internal secretion. If it is quite dry the seed or the plant quickly becomes moribund and soon dies if not supplied with moisture. After the nucellus of the seed or the conducting substance of the plant became fibroid, the first will not germinate or the second recover.

FURTHER STUDIES IN ELECTRO-PHYSIOLOGY

THE AUDITORY APPARATUS

A STUDY IN ELECTRO-PHYSIOLOGY

THE theory upon which the following thesis is based, or, I should prefer to say, the fundamental truth upon which it rests, is that the body functions are called into operation by a vital fluid, which although not electricity so closely resembles it as to be measurable by the instruments of precision used for the determination of electrical quantities and resistances and to be capable of expression in terms of electrical units.

Briefly, I hold that nerve force is generated in the lungs, with every inspiration, by the combination oxy-hæmoglobin, and that the electro-motive force is dependent upon there being a normal quantity of iron in the blood and of oxygen in the air.

It follows, logically, that the blood-stream being the carrier of energy the brain must be the seat of highest potential, while the nerves are conductors of that energy; their insulation being provided by the sheaths of medullated and the lipoid coatings of non-medullated nerves.

It is also postulated that the conduction of the nervous impulse is in accordance with the molecular theory of the propagation of electricity, that the unipolar cells in connection with the sensory nerves are storage cells, the bipolar cells condensers, and the multipolar cells multiple condensers. Assume also that each synapse is an inductive process and so transmitting impulse, that the sensory nerves are all "closed," and the motor and secretory paths "open" circuits and the study of physiological problems presents fewer difficulties.

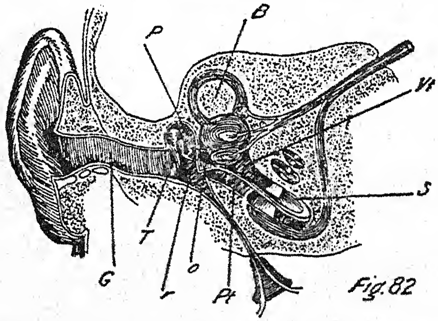
That nerve force is generated in the lungs many things go to show. A few of them may be mentioned without undue digression.

On the scale of a galvanometer of a sensibility of 4,000 millimetres per micro-ampere at 41 inches scale distance,

the hand-to-hand deflection yielded by a person in normal health is about 400 millimetres, at say, 10 or 11 a.m. During sleep, in the early hours of the morning, that deflection is exactly halved. The oxygen intake of man during the daytime is 400 cc. per minute; during sleep, 200 cc. per minute.

A person suffering from a deficiency of iron in the blood will not give more than 50 or 60 millimetres and if another who is perfectly healthy be kept in a room until the air becomes vitiated his deflection will fall appreciably, regaining its initial record upon the readmission of oxygen. It is just the same in plant life, and chlorosis in plants is curable by adding ferrous sulphate to the soil.

With this preamble we will proceed to examine what has been termed the "mechanism" of hearing.



SEMI-DIAGRAMMATIC SECTION THROUGH THE RIGHT EAR (*Czermak*).
G, External auditory meatus; *T*, membrana tympani; *o*, fenestra ovalis; *r*, fenestra rotunda; *B*, semi-circular Canal; *S*, cochlea; *Vt*, Scala vestibuli; *Pt*, scala tympani.

Our first illustration is a semi-diagrammatic section through the right ear, from Howell's *Text Book of Physiology*, and is numbered Figure 82.

In my view the external ear is the mouthpiece of the telephone transmitter, the drum the diaphragm, and the middle ear the microphone.

Contained in the apparatus of the inner ear are two fluids: the perilymph and the endolymph. In the latter, or in organs connected with it, the fibres of the auditory nerves are embedded.

These fluids are separated and, I believe, insulated from each other, are partly carried in what one might almost call coils, and, being in "closed" circuits, are in a condition of constant neuro-electrification. They, in my opinion, act as part of the human induction coil in assisting to convey and regulate the *quality* of the tone, and in this way the waves of sound impinging upon the drum of the external ear, and amplified and carried by the middle ear, would be received by the primary winding—the perilymph—and actuate the secondary—the endolymph—whence they would be transmitted in the form of neuro-electrical vibrations or waves to the brain.

In comparing the auditory apparatus with a direct working telephone it is unnecessary to say that the brain does not reply to the messages it receives from the sensory system, although it acts upon them. We do not, therefore, require a receiver at the ear end. A possible arrangement that obtains we shall see later on.

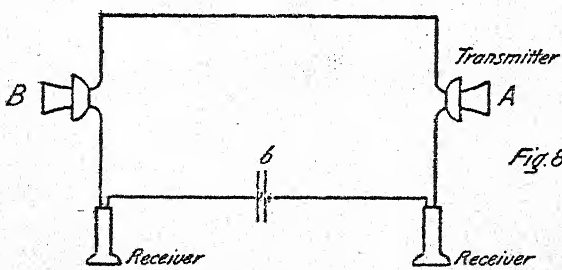


Fig. 83

The next diagram (Figure 83) is of a pair of direct working telephones in a "closed" circuit. It will be seen that the current from the battery, *b*, flows through both transmitters and receivers in series. When the transmitter at *A* is spoken into it alters the total resistance in circuit, more or less current flows through the transmitter and receivers and, the effect upon the receiver being approximately proportional to the variation thus produced by the transmitter, the diaphragm of the former vibrates in unison with that of the latter and in consequence reproduces the speech-waves.

In the case of the human telephone system, if I may call it so, it is only required that *A* (ear) should be able to signal to *B* (brain). The latter sends out messages or impulses by the "open" circuits of the motor and secretory nerves to actuate muscle and stimulate gland, so that we have merely to delete the receiver in the sensory circuit at *A* and suppose that at *B* to be muscular fibre or gland, to make the analogy fairly complete. We shall, however, have to modify our connections to meet the altered condition.

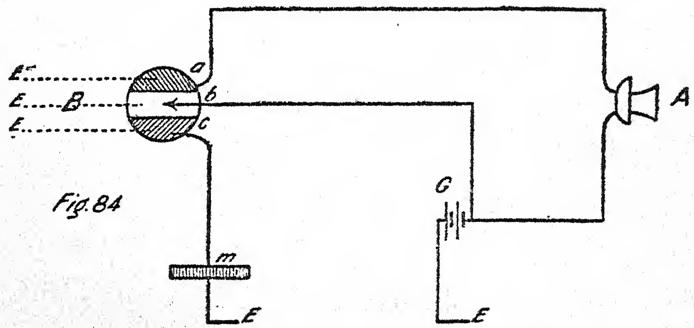


Fig. 84

The third figure is, of course, purely speculative. It divides that part of the brain with which we are concerned into three areas, *a*, *b*, and *c*.: *a*, we will call the sensory receptive area, *i.e.*, that portion of the brain which receives impulses from the sensory nerves ; *b*, is an imaginary zone charged directly by the blood-stream, and *c*, the motor area, provided with apparatus for dispatching messages by the motor and secretory paths ; a species, in fact, of departmental telegraph office.

All these areas, as well as the lung generating station, *G*, and the muscular fibre, *m*, are to earth (air) through the resistance of the medullary sheaths and lipoid coatings of the nerves, and the skin—that of the scalp being particularly high—so that we have a "closed" circuit from the transmitter at *A* to area *a* at *B*, but an "open" one from area *c* at *B* to the muscular fibre, *m*.

So far we have spoken of circuits, but it is necessary to study the construction of the telephone itself, because in that instrument, as well as in the ear, there is an arrangement

for the reproduction of quality of tone as well as of pitch.

This consists of a small induction coil, placed below or behind the diaphragm. In an open circuit a current passing through the primary would induce a current in the secondary winding. In a closed circuit anything altering the resistance of the primary circuit would react in a precisely similar way upon the secondary. In this manner, or by means of this device, not only is the note received at *B* of the same pitch as that sounded at *A*, but the same quality of note, as well as the very complex modification and superposition of notes upon which articulate speech depends, is preserved.

A microphone is capable of a great variety of forms. One of the earliest of them consisted of two or more pieces of carbon, resting loosely against each other. Great resistance is encountered at the loose contacts, and any vibration in the instrument makes rapid alterations in that resistance, and therefore equally rapid alterations in the total resistance of the circuit.

The vibrations which set in motion the drum of the external ear differ in no respect from those which excite the diaphragm of the telephone. We have only to imagine the middle ear responding to them as a microphone responds, the perilymph to be the primary and the endolymph the secondary winding of the induction coil to formulate what would appear to be a very reasonable theory.

There is little value, however, in new ideas unless they conform to natural laws and find some support in the accepted work of others.

Now, we cannot say that the middle ear is a microphone, in an electrical sense, nor show that alteration of resistance is produced within it by sound waves. It is probably mechanical in its action, and vibrations, we may suppose, are transmitted mechanically as far as the fenestra ovalis, where they are communicated to the perilymph. The perilymph is a liquid, and liquids are incompressible. But it is not only a liquid, it is a neuro-electrically charged liquid and assuming it to be the primary winding of the induction coil we should expect it to be the part to which current or charge is applied, and to be of greater sectional area

than the endolymph, or secondary winding. As regards the first the maximum supply of blood, and consequently of energy, is directed to the base of the cochlea, where, as it lies on the outside, the perilymph would be directly affected and charged. The second condition, *i.e.*, that of sectional area is not quite as clearly borne out, except in the cochlea, where the endolymph is restricted to the cochlear duct, and so lies in a narrow canal between the underlying scala tympani and the overlying scala vestubili, both of which contain perilymph.

However, as we shall presently see, other means are adopted to obtain the desired result.

The neuro-electrical potential of the perilymph and endolymph must be the same, because it is the potential of the blood. Moreover, exact equilibrium—the one thing imperative in all natural processes—between them is maintained, as, I believe, by their ganglia. The perilymph is contained in the bony labyrinth. Inside that, and of approximately the same shape, is the membranous labyrinth, filled with endolymph, so that in the cochlea the convolutions of the induction coil are to some extent carried out, and we may reasonably suppose the membranous substance to sufficiently insulate the weak natural current to render induction possible.

There is, obviously no room in the cranium for an induction coil of the familiar type, and owing to the absence of many turns of fine wire the intensification of the secondary circuit of such a coil is not obtained. All that we can see clearly up to this point is that anything tending to alter the resistance of the perilymph must of necessity tend to alter, by induction, the resistance of the endolymph, and if we were content to leave the matter there we need only postulate that as the fibres of the auditory nerves connect with the endolymph, the neuro-electrical waves set up by differences in resistance would, of course, in a sensory system, be conveyed to the brain.

But we should be overlooking the fact that intensification is, in all probability, called for, and disregarding what is an

essential and very important part of the human induction coil—the organ of Corti.

Before, however, going into that let us inspect a vertical section through the middle of the cochlea, taken from Schäfer's *Essentials of Histology.*

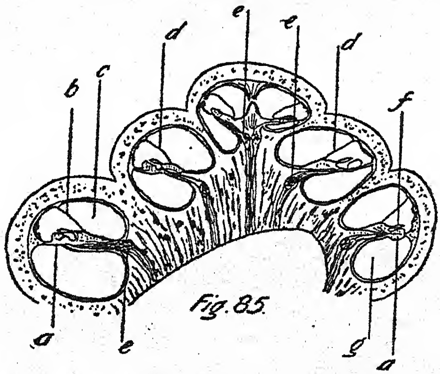


Fig. 85.

VERTICAL SECTION THROUGH THE MIDDLE OF THE HUMAN COCHLEA. (*After Schafer.*)

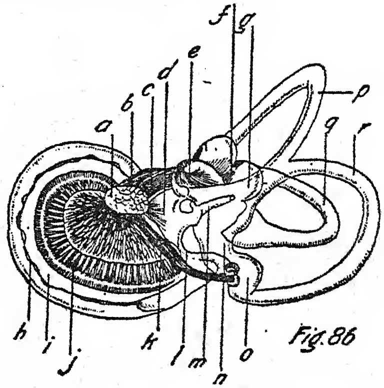
a, Basilar membrane; *b*, Canal of the Cochlea; *c*, Scala Vestibuli; *d*, Membrane of Reissner; *e*, Ganglia; *f*, Membrana Tectoria; *g*, Scala Tympani.

It is quite evident that in the cochlea—the only part of the labyrinth really spiral in form—the endolymph occupies a much smaller space than the perilymph; the latter filling the scalæ vestibuli and tympani, and the former the cochlear duct only.

Stretching across the scala vestibuli at an angle, and separating it from the cochlear duct, is a piece of connective tissue of the pavement variety, called the Membrane of Reissner. This tissue is non-conductive of the nervous impulse, is, from an electro-physiological point of view, dielectric in character and therefore capable, when between two conducting bodies, of transmitting neuro-electricity by induction.

We can now see that instead of the neuro-electrical waves set up in the endolymph going direct to the brain, they pass first to the organ of Corti, but before we proceed any further it is desirable to consider what is called the Acoustic Nerve;

I say "what is called," because it is in reality two nerves, and although both form part of the same apparatus only one of them need be taken into account in connection with quality of sound, and that—probably the true nerve of hearing—is the cochlear nerve.



MEMBRANOUS LABYRINTH OF A FIVE MONTHS' FŒTUS, viewed from its postero-medial aspect. (*Retzius.*)

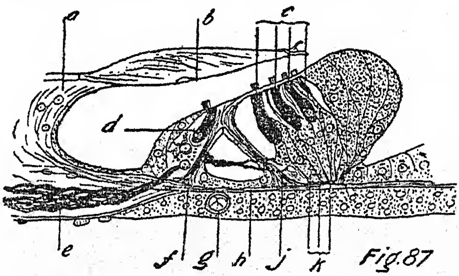
a, Cochlear nerve; *b*, Nervus facialis; *c*, Vestibular nerve; *d*, Macula acustica sacculi; *e*, macula acustica utriculi; *f*, Ampulia of superior duct; *g*, Sinus superior; *h*, Ligamentum spirale; *i*, Membrana basilaris; *j*, Branches of cochlear nerve to organon spirale; *k*, Branch of cochlear nerve to ampulla of posterior duct; *l*, ductus reuniens; *m*, Ductus endolymphaticus; *n*, Sinus inferior; *o*, Ampulla of posterior duct; *p*, *q*, *r*, Semi-circular canals.

Cunningham, in his *Text Book of Anatomy*, says: "The Nervus Acusticus . . . enters the brain at the inferior border of the pons. Its fibres spring from bipolar ganglionic cells in the immediate neighbourhood of the labyrinth. One group of these forms the spiral ganglion, the peripheral branches of which are distributed to the organ of Corti in the cochlea: another group constitutes the vestibular ganglion which distributes fibres to the ampullæ of the semi-circular ducts and the utricle. Although the central processes of the cells of these two ganglia accompany one another and are known collectively as the Acoustic Nerve, they *really remain distinct throughout*, in their mode of termination in the brain as well as in their peripheral distribution."

I am inclined to the opinion that the vestibular nerve serves for the conveyance of pitch, while the function of the cochlear nerve is the regulation of quality, or, in other words, the complex modification and superposition of notes upon which articulate speech depends.

Let us now revert to the organ of Corti.

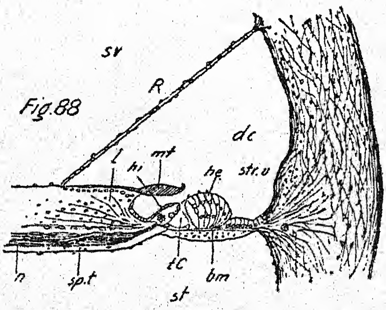
First we have it in section from Schäfer:



SECTION THROUGH THE ORGAN OF CORTI OF THE HUMAN COCHLEA. (*G. Retzius*).

a, Limbus; *b*, Membrana tectoria; *c*, Outer hair-cells; *d*, Inner hair-cell; *e*, Nerve-fibres; *f*, Inner rod; *g*, Blood-vessel; *h*, Basilar membrane; *j*, Outer rod; *k*, Cells of Deiters.

And next a vertical section of the first turn of the cochlea from the same source.



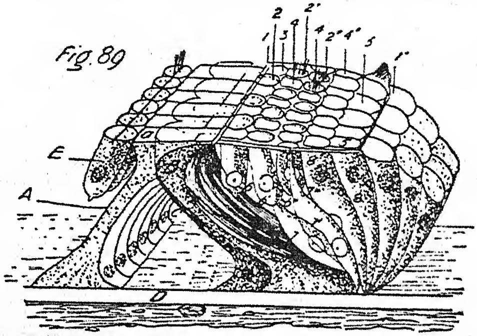
VERTICAL SECTION OF THE FIRST TURN OF THE HUMAN COCHLEA. (*G. Retzius.*)

sv, Scala vestibuli; *st*, Scala tympani; *dc*, Canal or duct of the cochlea; *sp.t*, Spiral lamina; *n*, Nerve fibres; *str.v*, Stria vascularis; *R*, Section of Reissner's membrane; *l*, Limbus laminæ spiratis; *mt*, Membrana tectoria; *tC*, Tunnel of Corti; *bm*, Basilar membrane; *hi*, *he*, Internal and external hair-cells.

These are chiefly interesting from the view they give of the nerve fibres and of the membrana tectoria, a process apparently protecting the hairs of the cells from injury. It is also very noticeable how the whole structure is built up to give strength and resist strain.

A more useful diagrammatic illustration, however, is given by Howell, in his *Text Book of Physiology.*

Fig. 89



DIAGRAMMATIC VIEW OF THE ORGAN OF CORTI.
(*After Howell.*)

A, Inner rods of Corti; *B*, Outer rods of Corti; *C*, Tunnel of Corti; *D*, Basilar membrane; *E*, Single row of inner hair-cells; 6, 6′, 6″, Rows of outer hair-cells; 7, 7′, Supporting Cells of Deiters; 1 to 5, Hair-cells.

Now, there are some 16,500 hair cells, similar to those shown in the last illustrations and I am going to suggest that they are condensers or Leyden jars, each of a slightly different electrostatic capacity and that the rods of Corti, together with the tunnel from which they rise, are designed, partly at all events, to give strength and secure insulation; much in the same way that a careful electrical instrument maker would mount the terminals of a standard condenser upon ebonite supports.

We must also remember that all these cells are in a closed circuit, in a liquid (the endolymph) and may reasonably postulate that the hairs are their antennæ, to enable them to receive and deliver charge.

That being so and both perilymph and endolymph being, in the absence of sound, in a condition of neuro-electrical equilibrium it follows that anything causing an alteration

in the total resistance of the circuit must also cause an alteration in the current strength in the circuit, because by Ohms' law, $C = \frac{E}{R}$, where C = current, E, electro-motive force and R, resistance.

In this case the electro-motive force does not vary, momentarily, for it is maintained by the blood supply, and therefore it is clearly the current that is variable with resistance, and it follows that with that variation more or less current must flow through the transmitter and receivers.

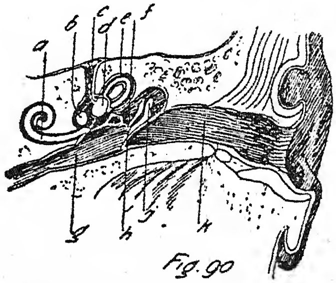
Let us assume that the 16,500 hair-cells, or Leyden jars, sufficiently represent every possible variation of sound intended to reach the human brain.

What would be the effect of rapid alterations of the total resistance of the circuit upon the organ of Corti? The hair-cells, or some of them, would discharge, or partly discharge, through their antennæ, recharge, and discharge again in, perhaps fractions of a second. And each discharge would, by reason of the distribution of the hairs, be in the form of waves, and those waves could only be communicated to the fibres of the cochlear nerve, and, by way of that nerve, to the receiving organ or organs of the brain.

Moreover, the fixed electrostatic capacity of the hair-cells would tend to regulate and correct neuro-electrical vibration and so bring about a finer appreciation of sound differences, while, as electricity concentrates upon points and projections the hairs themselves might well serve to bring about any required degree of intensification.

Taking cognisance of the labyrinth as a whole we see that throughout its ramifications the perilymph must inductively influence the endolymph, but two facts are very noticeable, *i.e.*, (1) that in the only part which is really spiral—the cochlea—the perilymph, or, as I suggest, the primary winding, is greatly in excess of the endolymph, or secondary winding as regards sectional area, while nerve-current in maximum quantity is supplied to the inducting body, the perilymph, as would obtain in electrical practice; and (2) that in the other part of the labyrinth—the utricle and semi-circular canals—where the distribution of the two fluids appears to be about even, a separate nerve receives

and carries the induced neuro-electrical waves to a department of the brain other than that served by the more complex and important cochlear nerve.



DIAGRAMMATIC VIEW OF THE ORGAN OF HEARING.
(*After Herrick.*)

a, Ductus cochlearis; *b*, Saccule; *c*, Ductus endolymphaticus; *d*, Utricle; *e*, Semi-circular duct; *f*, Tympanic cavity, with chain of ossicles; *g*, Eustachian tube; *h*, Membrana tympani; *j*, Recessus epitympanicus.

Hitherto I have regarded the Basilar membrane as being, in the main, a pavement for the organ of Corti and an environment of connective tissue for the cochlear nerve. But another view is possible.

The whole structure is estimated to contain about 24,000 strings or fibres, varying gradually in length, and resembling in general arrangement the wires of a piano. It is assumed by those who uphold the resonance theory that the vibrations of each string are communicated to a corresponding fibre of the cochlear nerve, through which the stimulus is conveyed to the brain as a nerve impulse.

I am not informed of the chemical nature of the strings in question but if they are capable of transmitting impulses it is clear, to my mind, that if their length varies their resistance would also vary and in that case their function as part of the transmitting apparatus can be understood.

In a mere thesis, such as this, the elaboration of minute detail is, obviously, out of the question, and explanation must, of necessity, be more or less elementary. We may, however, if we revert to the third illustration, usefully

consider, if only speculatively, the working of the system in some other sensory circuits.

Suppose the transmitter at A to be the hand instead of the ear, and the hand to become uncomfortably hot by reason of its proximity to a fire. The heat waves alter the total resistance of the circuit, a message is accordingly transmitted to area *a*, of the brain, and area *c*, acts upon it by ordering the voluntary muscles controlling the requisite movement of the arm to withdraw the hand to a safer position.

Again, we will imagine the transmitter at A to be the eye. The differences of light which form an image or a picture are not transmitted to the brain in exactly the same manner as are sound or heat waves but they are, I am convinced, the result of vibratory differences in resistance and, therefore, belong to the same category. A speck of dust is, we will say, approaching the eye, the resistance of the circuit is altered and area *a*, made aware of the fact. Orders are at once passed on to area *c*, for the eyelid to close, and it closes accordingly.

Broadly speaking, there are two classes of theories which seek, but do not profess, to explain the working of the auditory apparatus. Few people, I fancy, believe it to be due to chemical reaction. Personally, I would as soon accept the hypothesis that a Leyden jar could be charged by a Seidlitz powder. Concensus of opinion seems to attribute the so-called mechanism of hearing to mechanical vibration but with all respect to the authorities it is not, I submit, the function of *any* nerve to convey purely mechanical impulses, although excised nerve may respond to mechanical irritation. The two things, however, are not the same.

At the risk of labouring the point I repeat that the vibrations impinging upon the drum of the external ear are mechanical, but as well imagine the line wire of the telephone circuit to vibrate in unison with the diaphragm as to give credence to the statement that the auditory nerves are constantly in mechanical excitement.

And now let us consider some "faults" which commonly occur in the apparatus.

Conditions essential to the efficient working of the installation are that the drum of the external and the bones of the middle ear are free to vibrate, that the perilymph and endolymph are in normal quantity, that the organ of Corti is uninjured and that the line wire—the cochlear nerve at least—is adequately electrified.

Four "faults" which should be capable of repair are liable to occur, *i.e.*:

1. The drum of the external ear may be thickened, or overlaid by inflamed tissue—due, for instance, to rheumatoid arthritis—or by wax;
2. The bones of the middle ear may be clogged by catarrh or by inspissated mucus, so that they are not free to vibrate;
3. The Auditory nerves may be faulty, or
4. There may be a general deficiency of nerve-force, resulting in deficient neuro-electrification of the auditory nerves (purely nervous deafness).

In each case the sound waves do not reach the brain unimpaired because:

1. They are partly or wholly stopped, or rendered "woolly" by the drum;
2. If responded to by the drum they fail to set fully in motion the clogged bones of the middle ear;
3. The faulty line wire fails to carry them fully, or at all, to the brain, or,
4. The neuro-electrification of the line wire is too feeble to transmit them without loss, if at all.

When one of these faults occurs the system should be galvanometrically tested and the nature and locality of the fault ascertained. There is no difficulty about it. It is just an ordinary everyday test, except that battery power is not employed.

If the drum of the external ear is thickened, or the passage to it swollen by rheumatoid arthritis or by other causes contributory to local pyrexia it will yield a rapid excursion

of the light upon the Scale. So will the middle ear—tested by placing one electrode upon the forehead and another over the mastoid—if it is affected by catarrh; or it will give a subnormal deflection when the bones are clogged by urates. In much the same way the inner ear can be made to disclose its degree of conductivity or neuro-electrification by giving a measure of the nerve current in it as compared with the hand to hand deflection of the patient and a reading from the inner ear of a normally healthy person.

With the repair of any of these faults the electrician has no concern, because they happen to occur in the human body. If, however, they are considered anew in the light of the hypothesis I have advanced, remedial measures will readily suggest themselves to those medical men who are familiar with the construction and manipulation of electrical apparatus.

CANCER

A Possible Clue

THERE is, I think, convincing evidence that cell division is an electrical rather than a chemical phenomenon.

We may be sure that the nucleus of every cell loses its insulation during division because it breaks up and with the chromosomes forms a skein, and it is equally certain that the chromosomes lose their insulation temporarily for the reason that they split and in so doing double their number.

In no other way can their positions, first in the equatorial plane and, second, their attraction in two equal groups by the centrosomes, be adequately explained.

We may be sure also that the exoplasm does not disintegrate or undergo material change in the course of cell reproduction, for if for the briefest possible period of time the absolute insulation of the cell failed the process of mitotic division would automatically cease.

Logically then there must, after loss, be gain of insulation. The life of the cell, its development towards renewed mitosis, its power to receive and impart charge and the activation of its chemical processes depend mainly upon the perfect insulation of its various parts. I say "mainly," because if we disregard intra-cellular action we must consider the activating force as exterior to the cell and suppose the cell itself to receive charge by induction, in accordance with the theory of the propagation of electricity by molecular action.

It is a condition necessary to conduction that the cell be structurally perfect, for if its insulation is impaired it cannot receive or impart charge ; it can only become electrified.

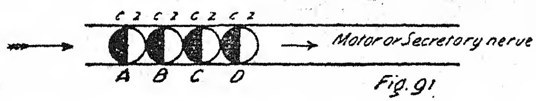


Fig. 91

Let us suppose cells *A*, *B*, and *C* to be in a complete and *D* in an incomplete condition and the charge or impulse to be in the direction of the arrow, *i.e.*, efferent.

The charge received by cell *C*, from the cell *B* (to the left) could only be diffused in the mass of *D*, and thence be dissipated along the path of least resistance.

For it to be imparted to another cell (*E* to the right of *D*) the latter must be structurally perfect. It may be argued that with the exoplasm intact the cell would in any case attain completion and survive, and upon that argument much depends.

To ponder the matter upon the lines of the theory I am about to advance it is necessary to assume that the pre-cancerous condition is inflammatory in character, that local insulation is broken down by a local rise of temperature or there is some injury which has produced an analogous effect.

As an inevitable consequence there is—there must be—an escape of nerve-current into wet tissue and an augmented neuro-electrical stimulus from that point along the path of least resistance to air and earth.

I am inclined to the belief that under such additional stimulus cell division in the area affected is forced to such an extent that a number of centrosomes are formed in certain cells and multiple division brought about, in which no process arrives at completion. Moreover, it is possible and even probable that *D*, and other cells to the right of it, would perish and with a similar fate overtaking other

cells in the over-ionised path of least resistance an irregularly shaped area of dead and rapidly proliferating cells is at least conceivable.

My experiments in vegetable electro-physiology point to this conclusion and in this connection we may recall that in the cells taken from a cancer of the breast it was shown by J. Arnold (Thoma's *Pathology, page* 454) that mitotic segmentation resulted in three segments and mitotic division into six segments; there being three centrosomes in the first and six in the second. With chromosomes always in equal numbers one can readily imagine this taking place, once the centrosomes are increased in number.

Several confirmatory facts present themselves. Cancer is said to have been caused by X-rays and by radium.

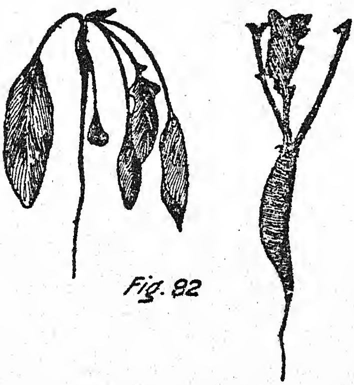
Thoma states that it is due to toxins and instances *paraffin*. But paraffin of a high flash point, such as medicinal oil, is not a toxin. We saw, however, from experiments at the Cancer Hospital that it facilitates the spread of the disease, for the simple reason that the dead cancer-cell is non-conductive of nerve-current, other cells in process of decay are devitalised, and paraffin is a dielectric, adding to their resistance. As a remedial agent paraffin could only act upon the exoplasm; the trouble is, however, *within* and not without the exoplasm.

I will now give some account of the experiments which led to the above theory.

If one electrifies the soil in a pot in which a flowering plant is growing—using only a low power—cell division is greatly stimulated, the leaves grow rapidly but the flowers frequently fall off and berries and fruits in course of formation exhibit a similar tendency.

To ascertain the effect of electrical stimulus upon root vegetables I sowed some seed of the Long French Radish in a 5-inch pot and electrified the soil by means of a dry cell—positive to bottom, negative to top; sowing other, control, seeds in the open ground. The former came up in

three days and exhibited abnormal upward growth *in the direction of the current*, the edible part being absent. Specimens of both are shown in the following illustration :



a, Electrified. *b*, Control from open ground.

A second experiment was with roots of grass. Both were identical as regards size and weight and the blades were cut 2-inches above the soil. No. 1 was electrified by means of a dry cell (positive to bottom, negative to top) and the other (No. 2) grown under normal conditions, in a cool greenhouse. The respective rates of growth were as follows :

Height of blades—

	Aug. 4.	Aug. 13.	Aug. 17.	Aug. 22.	Sept. 14.
No. 1	2-ins.	6-ins.	8-ins.	$10\frac{1}{4}$-ins.	14-ins.
No. 2	2-ins.	$2\frac{3}{4}$-ins.	$3\frac{7}{8}$-ins.	5-ins.	8-ins.

But there was this essential difference between the two. The blades of No. 1 were of hair-like proportions whereas those of No. 2 were vigorous and sturdy and far fewer in

number. Upon removal from the pots the roots of No. 2 were seen to be dense (completely hiding the soil). Those of No. 1 were fine white hairs, not covering five per cent. of the soil area.

Here also we have some evidence of abnormal growth, due to over-stimulation.

The effect of electrical stimulation upon Tomato plants after the fruit had formed, was to cause the fruit to ripen prematurely and even to burst.

I then took a Potato in process of germination with a view to ascertaining the effect of electrical acceleration of growth with a comparatively high electro-motive force and connected it by means of two steel needles, with a pair of Leclanche cells (3 volts).

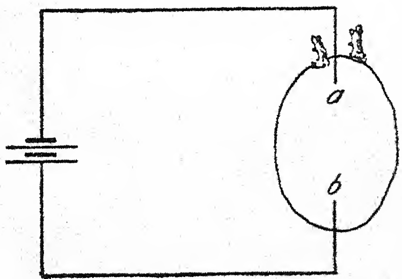


Fig 93

first perforating it to the depth of ¼-inch at *a*, in order to get diffusion as the nearest approach to a pre-cancerous condition of inflammation I could think of.

A week later the shoots became fibroid in character and the whole tuber was seen to be shrinking.

Twenty days after the connection had been made I cut the tuber in halves. The shoots were quite shrivelled and fibroid and the tuber presented the following internal appearance :

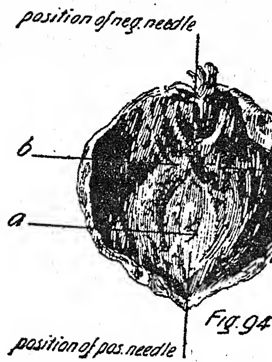


Fig. 94

a, Hard, dry formation yielding a low galvanometric deflection; *b*,*b*, Soft, wet, apparently putrescent area.

From the shoots I obtained deflections of 20 and 30mm., as compared with 2,000 or 3,000 from those of a healthy potato. Deflections taken from *b*, *b*, to *a*, varied from a few millimetres to off scale, and here and there I obtained reversals, showing that the tuber was not everywhere electrically dead. For the most part, however, the sign remained unchanged.

As a further experiment I selected a sound potato with shoots from two eyes:

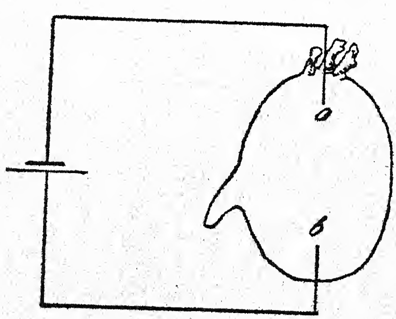


Fig. 95

It was perforated or pricked at *a*, as before, but this time I used a cell of 1.5 volts only. Perforation extended to a depth of $\frac{3}{4}$-inch, and the negative needle was afterwards inserted to a depth of $\frac{1}{4}$-inch; positive needle to $\frac{3}{4}$-inch.

A week later the shoots became dark in colour and unhealthy looking. Black fluid oozed from the positive needle (electrolysis) and a wet patch surrounded the point *a*; a hard lump forming about *b*.

In seventeen days the top shoots had become quite fibroid and the side one fell off.

Measurements were taken showing the tuber to have shrunk 15 cm. each way. The following is an illustration of it in section:

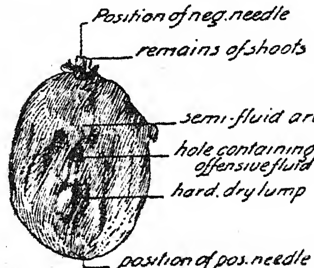


Fig. 96

In both these experiments electrification was continued for twenty days; the first with 3 and the second with 1.5 volts.

Some three days after it had been cut a white mould appeared upon the area marked "semi-fluid" in the illustration, and elsewhere there was a noticeable absence of the starch-like secretion which a healthy potato throws out upon cut surfaces. The following is a drawing of the same half of the tuber ten days after cutting:

Fig 97

I next took a comparatively young tuber without any shoots and gave it twenty days' electrification with 2.5

volts in the manner previously described; desirous of seeing if the age of the vegetable made any appreciable difference.

Twenty-four hours later the area around the negative needle was discoloured by moisture over some ¾-inch, and a blackening patch was forming at the positive end.

After twenty days the tuber had lost ½-oz. in weight (from 2-oz. to 1½-oz.) and in section presented the following appearance:

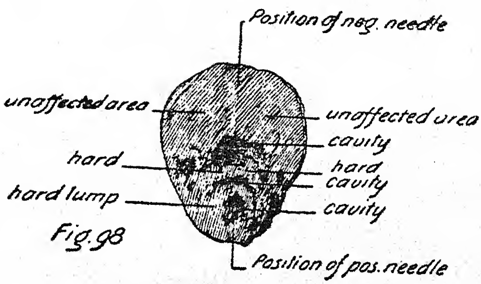


Fig. 98

A sketch of the other half may be helpful.

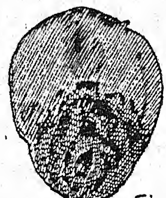


Fig. 99

This differed from the others in that the morbid growth, if I may call it so, was more spherical than ovoid in shape while the discoloured part extended half way from bottom to apex and thence was linked with the negative connection by the band shown in the drawing.

In the darkened lower half also there were three cavities, two of which may have been, but in all probability were not, due to electrolysis, as perforation did not extend so far. These cavities contained a somewhat offensive fluid, while the upper part of the area partook of the semi-fluid character referred to in the last experiment.

To avoid recapitulation I refer the reader to the Chapter

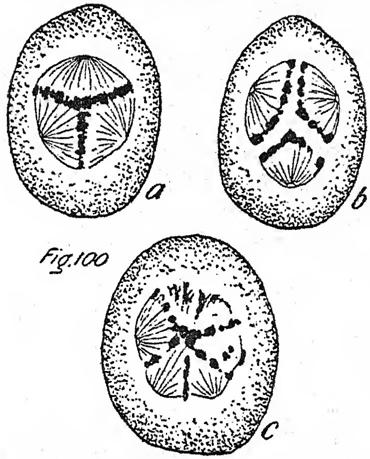
upon "Electrical Stimuli," in which will be found other experiments with potatoes; the side growths being suggestive, in my judgment, of multiple cell division.

In this series the final trial was with some seeds of the Giant Rocca Onion, sown in a 5-inch pot and electrified; 4 volts, positive to bottom and negative to top of soil.

When sown in the open ground these seeds would not send a shoot above soil for at least two months. Under electrification they appeared in nine days, grew 4-inches in nineteen days and one pulled seventy days after sowing was 7-inches in height with a root like that of the Radish but without any sign of bulb. The other plants were rotting.

I am not going to suggest that in the foregoing experiments there is substantial evidence that the morbid conditions produced by electrification resemble in their character the changes brought about in animal tissues by Cancer. To the lay mind they seem to, and indeed may, be analogous; and I would point out two things, *i.e.*, (1) under the stimulus of electricity of wrong sign, cell division is, as I believe, forced. to the disadvantage of the plant, and (2) under comparatively low electro-motive forces, hard, dry lumps are apt to form at the part or parts where the electrolytic dissolution of iron is most active; the fluid formerly present in that area not only being driven to the kathode but the protoplasm killed. It does not call for an undue stretch of the imagination to conceive the semi-fluid areas to be dead cells—the secondary deposits as it were—and the mere fact that the hard lumps are dry goes to show, even without the confirmation of the galvanometer, that they are deficient in electro-vitality.

I have only made brief mention of the work of J. Arnold but it seems to lend support to the views I hold and to be, in any case, worthy of close attention. I extract the following from Thoma's *Pathology and Pathological Anatomy*: "When the cell and nucleus divide into more than two portions, the mitotic processes are exactly similar, as was shown by J. Arnold. Skein and star, equatorial plate and achromatic spindle occur in forms which can be most easily understood by reference to the following figure:



a,b, Mitotic segmentation into three segments. (*After J. Arnold.*) *c,* Mitotic division into six segments. From a cancer of the breast. (*After J. Arnold.*)

"These still carry out the idea of segmentation in so far that the geometric regularity of the forms is preserved and the divisions show geometric similarity. This similarity is not completely absent even in those asymmetric forms which are occasionally developed (Hansemann). These may be of great importance in certain circumstances, if two intrinsically different daughter cells are produced.

"In *Fragmentation of the Nucleus* (J. Arnold) the simple geometric formation of the mitotic figures is altogether absent. The whole 'habitus' is different, but direct and indirect fragmentation can still be differentiated. In direct fragmentation the nucleus splits into numerous subdivisions without any preliminary increase or rearrangement of its chromatin. In indirect fragmentation there is, on the other hand, an increase of the chromatin, which assumes an irregular formation. It may be like a horse-shoe, or ragged, or in the shape of a ring, a network, or basket. Between the lobes and processes of the chromatic figure are seen fine striated achromatic connecting lines. During this process, in consequence of the irregular division of the chromatin figures and the transformation of the several parts into resting cell nuclei, large cells with many nuclei, *giant cells*, are occasionally formed. An endogenous

cell formation appears, in other cases, to be combined with this peculiar nuclear division. It is as yet impossible, unfortunately, to follow this nuclear fragmentation directly in living tissue under the microscope; but it may be stated in favour of the above explanation of nuclear fragmentation that it mainly occurs in the cells of actively growing tissue . . . and in rapidly growing tumours."

May we not take it, in view of what we have seen of the effect of over-stimulation upon vegetable cells, that "actively growing tissue" and "rapidly growing tumours" suggest over-ionisation ?

"There is, lastly, a particular form of cell division to be described which greatly differs from the foregoing varieties, in that one portion of the divided cell is completely devoid of any part of the nucleus. This discovery was first made by Lavdowsky. I am in a position to confirm this, on the strength of experiments made before Lavdowsky's communications. I placed under the microscope some white blood corpuscles from a frog, in aqueous humour taken from the same animal, warmed them to 20-32°c., and stimulated repeatedly with the induced electric current. By this means I observed, in different experiments, the process of division." . . . There was "separation of a portion of the cell protoplasm from cells which went through active amœboid movements on the cover glass. Lavdowsky calls this '*cell division by force*,' and suggests that the two portions of the cell move in different directions by means of their amœboid power and thus tear the protoplasm apart."

In *Studies in Electro-Physiology* I advanced the opinion that amœboid movement arises from electrical attraction and repulsion in accordance with the experiments of Ampere.

"This is a plausible description of the process; but it seemed to me that the process was rather *a disintegration of the cell*." The italics are mine.

I will now quote from the source previously mentioned, an account of an experiment made by Dr. Carrel with a small piece of cancer tissue :

"The experimenter was now able to watch this phenomenon taking place under his very eyes. The new

Waeles book

cells would start precipitately from the main tissue; they would become spherical in shape, then oval, and then oblong. One end would shoot out, like a microscopic comet, and form a tail; just as quickly, this tail would separate itself from the main body, and perhaps ultimately give birth to new cells of its own."

That does not in the least resemble ordinary mitosis but is very like Lavdowsky's "cell division by force." Thoma gives an illustration of this:

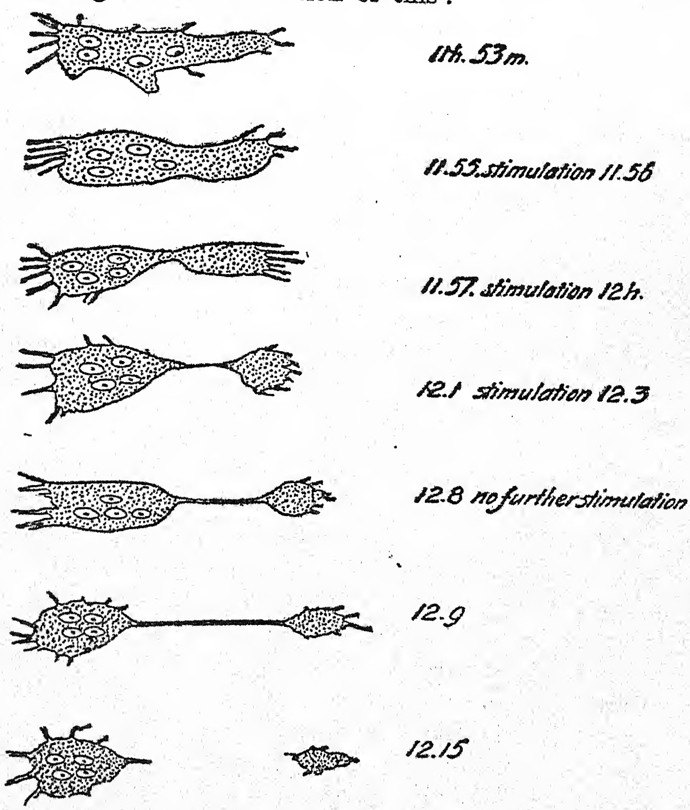


Fig. 100a

FIGURE 100A.—A white blood corpuscle from the frog, in aqueous humour on a warm cover glass. Changes observed during repeated stimulation by electricity. The numbers at the side show the time of day. (*After Thoma.*)

The whole process occupied twenty-two minutes and it will be noted that the effect continued twelve minutes after stimulation had been discontinued.

I do not wish to advance even the shadow of a claim that I have discovered the origin of cancer. It would indeed be cruel to do so unless the fullest proof could be brought forward in support. But I should be wanting in duty to my kind if I withheld any fact that might upon further enquiry be found to throw light upon the problem.

When the cause of any particular disease is unknown and its pathology imperfectly understood it may seem empirical to suggest even a possible method of treatment, as treatment should be the logical outcome of pathological knowledge and not of mere opinion. But we have from repeated observation obtained certain results and one definite fact, *i.e.*, the cancer cell in its devitalised condition *is non-conductive of nerve-current.*

Now when a poultice is applied in relief of an inflammatory affection it acts, from an electro-physiological point of view, by lowering resistance and enlarging the area of the path to air and earth, so that with diminished neuro-electrical pressure there is an amelioration of the unfavourable symptoms.

In cancer, before it has broken down, one intelligent measure would seem to be to restore conductivity to the tissue and to open up a low resistance path to air and earth by ionic medication. When the cancer is superficial, as in the breast, I have witnessed its complete disappearance in six weeks under the application of a pad of cotton wool steeped in an ionic solution (1 mgm. to the litre) of Sodium chloride. Recently an undoubted case of Carcinoma of the breast which had resisted radium treatment, yielded to ionic medication with Sodium chloride, followed by hypodermic injections of an ionic solution of permanganate of potash, with complete recovery.

In this there is no proof, but some confirmation. In all I have seen six of such cases and in all of them the remedy proved successful. Theoretically metabolism cannot proceed if there is and while there is a disturbance of neuro-electrical

equilibrium and if, as I believe, there is, in cancer, over-ionisation of cells in a certain area and from that area along the line of least resistance to air and earth such a disturbance would be present. Granting the pre-cancerous condition to be inflammatory in character we are reminded that the effect of electrical stimulus continues even after disconnection of current. An impetus is given to growth and that growth may go on after the inflammation has ceased. If the neuro-electrical pressure is sensibly lowered the tendency would be in the direction of a restoration of the normal, and that is the scientific basis underlying all treatment.

SLEEP; NARCOSIS AND ALLIED PHENOMENA

THE conditions that favour sleep are stated by Halliburton to be:

(1) A diminution of the impulses entering the central nervous system by the afferent channels, and

(2) Fatigue, as this diminishes the readiness of the central nervous system to respond to stimuli.

"Of the parts of the central nervous system," he adds, "the spinal cord is always less deeply affected than the brain, but even the brain is never entirely irresponsive. . . . Sensations of sound appear to be the last to disappear as sleep comes on, and the first to be realised on awakening."

Some distinction must, I think, be drawn between the afferent channels. Sensory nerves cannot be taken together as a whole. The Optic as well as the Auditory nerves are extensions of the brain and the latter should, in my view, be as responsive to light as to sound.

The logical outcome of my own work upon the subject is this:

Consciousness is in direct ratio to brain potential. Anything that interferes with the supply of energy to the brain or with the electrostatic capacity of the cells of the brain must diminish consciousness. It is merely a question of degree.

Howell is not far from the truth in attributing the sleepiness which follows a heavy meal to the mechanical effect of a dilatation of the abdominal vessels in producing a diminished blood flow through the brain but he is, in my opinion, wrong in believing the sleep that normally comes on at the end of the day to be produced by cerebral anæmia following dilatation of the blood-vessels of the skin, although that may be a contributory cause. The true explanation

is probably to be found in the diminished oxygen intake and therefore diminished generation of neuro-electricity, rather than in vaso-motor fatigue.

Halliburton says: "Sleep has been attributed by some to changes in the blood supply of the brain, and ultimately referred to fatigue of the vaso-motor centres. The existence of an effective vaso-motor mechanism in the cerebral blood-vessels themselves is problematical; so that if changes occur in the cerebral blood pressure or rate of flow, they are mainly secondary to those which are produced in other parts of the body. Plethysmographic records from the arm of a sleeping man show a diminution of its volume every time he is disturbed, even though the disturbance may not be sufficient to awaken him. This is interpreted as meaning a diminution in the blood of the body, and a corresponding increase in the blood flow through the brain. It is, however, quite possible that the vascular condition is rather the concomitant or consequence of sleep than its cause."

We may be quite clear upon one point; whether the vascular condition is or is not a consequence of sleep, the blood is the carrier of energy and increased blood-flow *must* mean increased brain potential.

"Some of the theories," continues Halliburton, "to account for sleep have been chemical. Thus certain observers have considered that sleep is the result of the action of chemical materials produced during waking hours, which have a soporific effect upon the brain; according to this theory awakening from sleep, is due to the action of certain other materials produced during rest, which have the opposite effect."

According to this theory also one would need, for these chemical processes to continue an undeviating course throughout life, to eat and drink exactly the same things day by day!

"Obersteince has gone so far as to consider that the soporific substances are acid in nature, and others regard them as alkaloidal."

It is difficult to follow the reasoning here and I quite agree that theories such as these rest upon the flimsiest

foundations and have not been found to stand experimental tests.

"Then there are what we may term histological theories of sleep, and these are equally unsatisfactory. The introduction of the Golgi method opened a fresh field for investigators, and several have sought to find by this method a condition of the neurons produced by narcotics, such as opium and chloroform, which is different from that which obtains in the waking hours.

"Demoor and others found in animals in which deep anæsthesia has occurred, that the dendrites exhibit moniliform swellings, that is, a series of minute thickenings or varicosities. On the strength of this observation, what we may call a biophysical theory of sleep has been formulated; in the waking state, the neighbouring nerve units are in contact with each other; transmission of nerve impulses from neuron to neuron is then possible, and the result is consciousness; during sleep the dendrites are retracted in an amœboid manner; the neurons are therefore separated and the result is unconsciousness."

We might usefully ponder that theory were it not already discredited.

"Lugaro . . . takes the precisely contrary view. He was not able to discover moniliform enlargements, and his biophysical hypothesis is that the interlacing of dendrites is much more intimate during sleep than during consciousness. He therefore explains sleep by supposing that the definite and limited relationships between neurons no longer exists, but are lost and rendered ineffective by the universality of the connecting paths."

I may be dense but I fail to see in this hypothesis any explanation of the phenomenon of sleep.

"A more satisfactory histological investigation of the effect of anæsthetics on nerve-cells was carried out by Hamilton Wright. . . . In extreme cases the cells look as though they had undergone a degenerative change, and after eight or nine hours' anæsthesia in dogs, even the nucleus and nucleolus lose their affinity for basic dyes. The change, however, is not a real degeneration, and passes off when the

drug disappears from the circulation. . . . The pseudo-degenerative change produced by the chemical action of the anæsthetic no doubt interferes with the normal metabolic activity of the cell-body, and this produces effects upon the cell-branches."

From an electro-physiological point of view the normal metabolic activity of the cell-body would be interfered with if the electrostatic capacity of the cell was interfered with and we have the undoubted fact that anæsthetics such as chloroform and ether largely increase the resistance of the nerve substance or alternatively, lower the electrostatic capacity of cell-bodies.

"The theory which has met with most favour in relation to anæsthetics, however, is that known as the Meyer-Overton hypothesis; this theory, which has received abundant confirmation by numerous observers, points out that the cells are easily permeable to the volatile anæsthetics owing to the presence of fat and lipoid material in their plasmatic membrane. It can hardly now be doubted that the solubility of the volatile anæsthetics in the lipoids of the membrane (or what comes to the same thing, the solubility of the lipoids in the anæsthetic) is an important factor in anæsthesia; the anæsthetic thus enters the cell easily, and throws the lipoid constituents of the protoplasm . . . out of gear, the net result being a lessening of the oxidatine changes which are essential in active vital processes."

In other words lessening of intra-cellular neuro-electrical generation and transmission.

"But," as Halliburton remarks, "the artificial sleep of a deeply-narcotised animal is no criterion of what occurs during normal sleep. The sleep of anæsthesia is a pathological condition due to the action of a poison. The drug reduces the chemico-vital activities of the cells, and is, in a sense, dependent on an increasing condition of exhaustion, which may culminate in death. Natural sleep, on the other hand, is the normal manifestation of one stage in the rhythmical activity of nerve-cells, and though it may be preceded by fatigue or exhaustion, it is accompanied by repair, the constructive side of metabolic activity. This

is true for many other organs in addition to the central nervous system; sleep is a time of repose for them also, but the amount of rest varies; the voluntary muscles, except those concerned in breathing, will rest most, but the heart continues to beat, the urine is still being secreted, the processes of digestion go on, so that for such organs activity is only diminished."

All this is in perfect harmony with the theory I have advanced. If, as I claim, body functions are called in operation by neuro-electricity generated in the lungs by the combination oxy-hæmoglobin it follows that the blood is the carrier of energy, that by reason of its greater blood supply the brain is the seat of highest potential and that its cells possess electrostatic capacity, or they could not send out impulses.

Now, the oxygen intake of man during the daytime is 400 cc. per minute (negative oxygen); the positive substance, the iron, is partly consumed in the process of generation. At night the oxygen intake is exactly halved so that generation of neuro-electricity is also halved and the brain cells are not charged to the same potential. Body processes go on because there is not a cessation but only a diminution of energy—supply. Rest is, of course, imperative. Fatigue always interferes with the generation of nerve force; and mental fatigue to such an extent that if the normal hand to hand deflection of a healthy man is 400 mm. upon the scale of the galvanometer at 10 a.m., it may fall to 20 mm. after a long and anxious day's work.

As regards the heart, I have explained elsewhere that if generation is halved so also is inhibition.

Sleep is, of course, as Halliburton says, "the period of anabolism, repair and growth."

There are two conditions to which my attention has been specially directed. Those are (1) somnolency after a heavy meal, and (2) the effect of stimulants, with especial reference to alcohol.

A full measure of consciousness, of mental activity is, in my view, dependent upon the maintenance of brain potential at its maximum.

The quantity of nerve-current generated by the act of breathing is only sufficient for the requirements of the body from moment to moment. If the expenditure of energy called for to digest a heavy meal exceeds the quantity normally assigned to the digestive apparatus reserves must be drawn upon and the brain potential lowered.

In the same way, I believe that the feeling of exhilaration produced by stimulants generally, but particularly by intoxicants, is due to an effort on the part of the nervous system to throw them off as toxins. The effect of brandy, for example, as shown by the hand to hand deflection is first to exhibit an increase of energy and later, an hour or so afterwards, a mischievous reaction.

It suggests to my mind poking up a fire without putting more coal upon it. There is a temporary blaze, but the fire soon dies down to a lower level than it would have done if left alone.

In conclusion I may usefully add a few notes made upon the young sleeping with the old.

Children generate more nerve-current than adults because they not only have to live but to grow, whereas generation begins to fall off with approaching old age.

To take actual figures which obtain. A girl of ten or twelve years of age would give a hand to hand deflection of about 500 or 600 mm., and a woman of 70 about 80 to 100 mm. Let us call them 600 and 100 respectively and to take an extreme, but not at all an unlikely, case suppose the girl to be positive and the woman negative.

At night, during sleep, those deflections—the measures of nerve-force or energy—would be halved, so that the figures would become 300 and 50 respectively, and as the 50 negative must be deducted from the 300 positive and neuro-electricities would find a common level as assuredly as would water, there would be a sum total of 250 mm. to be divided between the two.

As a result the vitality of the girl would be represented by 125 mm. instead of 300, and it is difficult to see how this could be otherwise than harmful to her, although the woman would benefit.

SOME FAMILIAR VEGETABLES ELECTRICALLY CONSIDERED

SOME FAMILIAR VEGETABLES ELECTRICALLY CONSIDERED

GENERALLY speaking, those parts of vegetables which yield a negative galvanometric reaction are unsuited to human consumption, but it does not necessarily follow that because those negative parts are fibrous or inedible, or that poisons are, as a rule, present in excess in the roots, stem and venation of plants, all are equally unsuitable for food, or are to be avoided on account of their toxins. Poisons in suitable doses enter into nineteen out of every twenty prescriptions written, and in vegetables their proportions are so adjusted by the Great Physician as to be harmless in the quantities we ordinarily assimilate. Other vegetable substances, such as Rhubarb leaves—and in this case the poison is principally contained in the negative venation—give warning of the dangerous character of their chemical secretion by setting up acute pain when they are eaten, and it is quite within the bounds of possibility that much of our knowledge of vegetable poisons has been derived from the painful experience of venturesome or foolish persons.

With this preamble we may proceed to the consideration of some of the vegetables which enter largely into our diet, commencing with examples of that interesting family, the Cabbage tribe!

It is well to premise, however, that although plants are mainly dependent upon the earth for their electrification they are not entirely so. Nature very seldom, if ever, relies upon the constant, unintermittent maintenance of any single condition when life depends upon it, and it is, for that and other reasons, probable that electrical generation goes on in the plant itself. Most, if not all plants contain iron and all of them inspire oxygen.

During periods of drought the root supply of current may, conceivably, be cut off by non-conducting dry soil, and if that current is necessary to the well-being of the plant it would perish had it not some other source of supply ; whereas so long as its protoplasm remained in a fluid or semi-fluid condition it would, with some measure of independent generation, be better fitted to endure hardship. The outer dark green leaves of the Cabbage contain a comparatively large quantity of iron (17 mgms. per 100 gms. of substance) and those leaves—standing out from the more closely folded leaves of the heart of the plant—have the largest oxygen intake.

I propose to give three examples of the Cabbage tribe, *i.e.*, a Summer Cabbage, a Brussels Sprout and a Savoy. There are many other plants, such as the Lettuce, etc., which it is unnecessary to mention because they are, in their electrical structure, almost identical with the Cabbage.

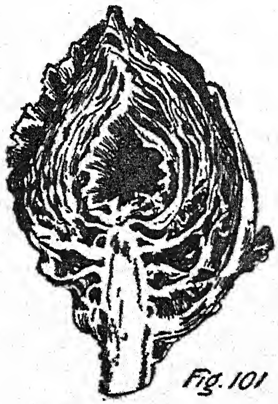


Fig. 101

SECTION OF CABBAGE.

Figure 101 depicts what is probably the most succulent and digestible member of the whole family in that the positive portion—the fleshy part of the leaves—largely exceeds in bulk that of the negative venation. It is, in fact, in that respect, an exaggerated Brussels Sprout, which everyone knows is one of the most tender inhabitants of the kitchen garden. Figure 102 will enable us to compare them.

Fig. 102

SECTION OF BRUSSELS SPROUT.

I have said that the outer leaves contain a maximum quantity of iron and have the largest oxygen intake. My readers will also observe that they have also the largest veins and therefore carry or are able to carry a considerable quantity of current.

In both the drawings the negative stalk shows up prominently but this is generally excised when the cabbage is prepared for the pot, while that of the Brussels Sprout is at least curtailed. We are led by instinct to reject, or at all events to partly remove, the negative parts of vegetables and fruits. The root of the Cabbage and the coarser veins are fibrous and are, or should be, cut away prior to cooking.

In strong contrast to the others is the Savoy :

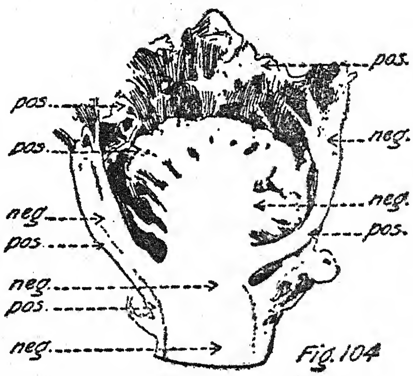
Fig. 103

SECTION OF SAVOY.

In this the negative venation is in preponderance and as

a consequence the Savoy usually boils hard and has neither the delicacy nor flavour of the others.

Somewhat akin—and yet not—is our favourite, the Cauliflower :

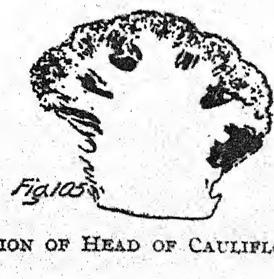


SECTION OF CAULIFLOWER.
(*Some outer leaves removed.*)

Although it is only partly and very faintly shown in the drawing there are in the vegetable itself clear lines of demarcation between the negative and positive systems. The stalk and main veins are negative only as regards the central white portions. The outer layers contain chlorophyll.

The so-called leaves—or what may more appropriately be termed the heads—of the cauliflower, are positive, and in order that they may receive charge the inner leaves fold closely over them. These leaves in all probability have their supply from the principal generators—the iron-containing green outer leaves—and are therefore not entirely dependent upon air as the vehicle of positive charge.

A section through the "heads" is not without interest :



SECTION OF HEAD OF CAULIFLOWER.

We have now another familiar object in the Scarlet Runner Bean.

In this the seeds are connected in series-parallel by means of insulated contact-pieces, the membrane covering which appears to be continuous with the seed capsule:

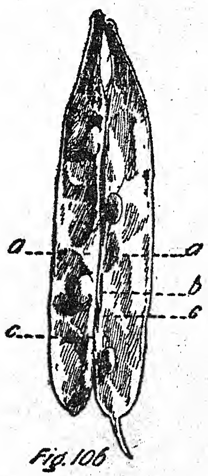


Fig. 106

SCARLET RUNNER.

a, a, Placental growth; *b,* Ventral suture; *c, c,* Subsidiary leads from Stalk.

In the above figure the negative (earth) lead splits at the apex of the stalk and is carried along the ventral suture in two parts (as in the Pea), the seeds being arranged alternately upon the two circuits. The siliqua itself is porous and with the exception of the stringy negative fibres, or leads, is of positive sign. It should, therefore, be fit for food.

At the end of the stalk, where it joins the siliqua, there is a fibrous point which seems to shut off the front seam from the leads along the ventral suture. The ovary is divided into two by a placental growth, *a, a.*

The two succeeding sketches are of the Vegetable Marrow and Cucumber in transverse section and call for little or no explanation. The central part is negative, that surrounding it positive, and the rind merely a high resistance covering to conserve energy. The inner circle in each case

connects with the stalk ; the positive flesh taking its charge, at the flower end, from the air.

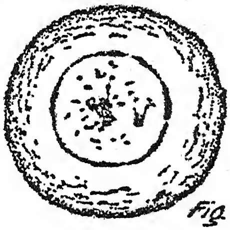


Fig. 107

VEGETABLE MARROW.

Fig. 108

CUCUMBER.

The Loofah and the Gourd are vegetable but certainly not familiar to the cook. My reason for introducing them is that they present a very remarkable contrast to the Vegetable Marrow and the Cucumber ; nearly the whole of their substance being negative and either poisonous or fibroid or both.

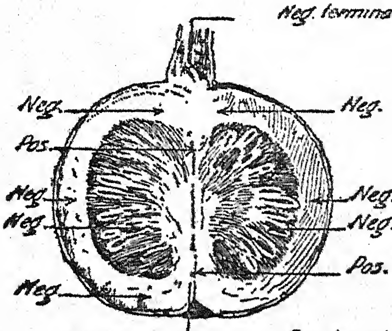


Fig. 109

SECTION OF GOURD.

The Secretion is only slightly acid and instead of staining steel has a cleansing effect upon it. The positive (flower) end connects with the central vertical line as far as the plug at the posterior part of the stalk in the Figure. All the rest, so far as I could determine, is negative. The stalk was ridged and appeared to carry several conductors communicating with the corrugations of the stalk.

The Loofah is just like a Cucumber filled with fibrous connective tissue.

Amongst root vegetables the Turnip and the Swede are valuable foods by reason of the great bulk of their positive flesh, but, unfortunately, their jacket or outer coating is not of sufficiently high resistance to conserve their energy and therefore the Turnip—to a much greater extent than the Swede or Mangel Wurzel—becomes sponge-like and tough soon after it is removed from the earth—its source of electrification. The following figure will serve to illustrate its electrical structure :

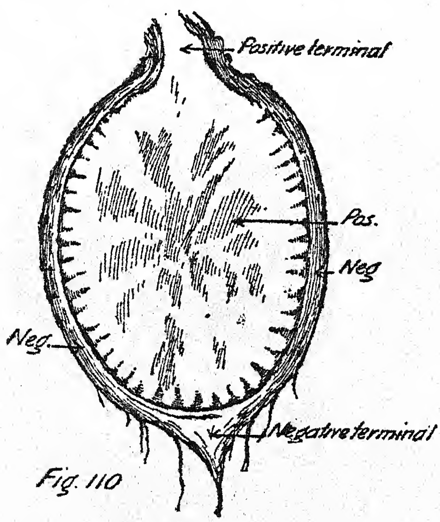


Fig. 110

Another beautiful example of the work of the Great Electrician is the Tomato :

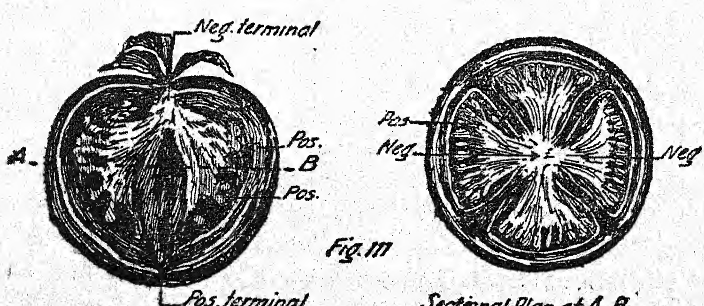


Fig. 111

The Maltese Cross in the sectional plan is very remarkable and is especially interesting as this vegetable comes to us from the East.

Next in order we will take that wonderful tuber, the Potato.

Before describing it in electrical detail I will quote an account of it which appeared in *The Catering World* of May, 1917.

"The Potato, being a stem, it is, like the latter, provided with a ring of vascular tissue. All along it, just beneath the skin, is a cylindrical supply of slender pipes. The netting shown in Figure 112 consists of hollow pipes or fibres grouped together.

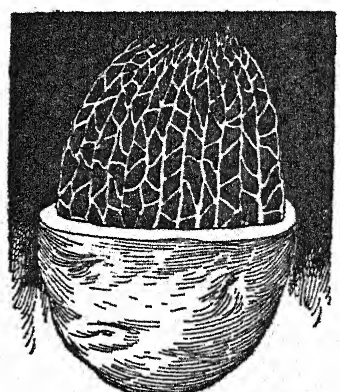


Fig. 112

When the plant is growing it is along these tubes that the sap is conveyed to feed the potato, which is filled with food intended primarily to nourish the buds, *i.e.*, the eyes, when they grow into new plants. Air also travels along these tubes."

As one of our American cousins would say, that description leaves me cold! I should like to be able to follow those tubes in their ramifications and see precisely with what parts of the tuber they connect. Perhaps my own drawing may throw some light upon the subject:

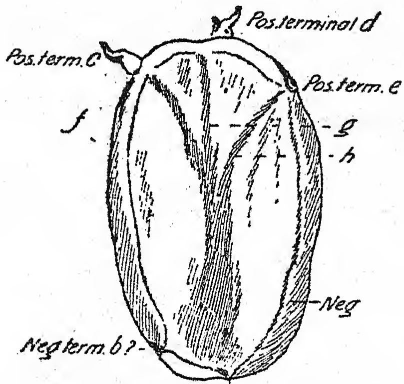


Fig. 113

as it exhibits the Potato in its electrical aspect.

The *Plant* receives its supply of current direct from the earth, but is open to doubt whether such is the case with the tubers to which it gives birth. They are connected to the parent plant by a filament, or filaments—not altogether unlike the umbilical cord and nerve of the human—through which, or by means of which, they are energised. In the specimen illustrated I can trace only two eyes to which such filaments might have been attached (marked *a*, and *b*). They are negative terminals communicating with the outer negative system, while *c*, *d*, and *e*, are positive terminals of the lines *f*, *g*, and *h*. It is only where these slightly darker lines reach the jacket that we find a live or prolific eye. The unprolific eyes, so-called, are those by which the tuber is attached by a filament to the parent plant.

In all probability the tubes (Figure 112) or at all events those tubes through which air passes, connect directly with the prolific eyes.

In my belief all members of the vegetable kingdom are provided with a repair outfit, and in this respect the potato is well endowed. Very shortly after being cut it exudes a starchy substance which dries rapidly and, forming a film over the cut surfaces, restores in some measure, if not entirely, the impaired insulation, as well as preventing loss, by evaporation, of the moisture without which it must

become electrically inert. This tuber will, in fact, keep longer and grow better after being injured than any other vegetable with which I am acquainted.

Between the Potato and the Jerusalem Artichoke there are several essential points of difference:

Fig. 114

The latter is covered with root filaments, is distinctly bi-polar as regards the ends, and does not seem to be provided with so efficient a repair outfit as the Potato. In common with the latter it has a marginal negative system and several positive terminals, but it is probable, from the number of root filaments, that instead of being dependent upon the mother plant it derives its electrical supply directly from the earth.

It is, no doubt, new to be told that not only is every fruit, every vegetable, but indeed every leaf of every vegetable is an electrical cell which retains full activity during such time as it is structurally perfect, but every addition to our knowledge is new, in the sense that it is something we did not know before.

One of the earlier great authorities upon vegetable life, Sachs, did not, so far as I am aware, carry out any experments in electro-biology but he came very near to the truth

when he wrote: "We may suppose that in the ordinary life of land plants especially during the continually altering differences of electrical tension between the atmosphere and the soil, equalisations take place through the bodies of the plants themselves. The land plant rooted in the soil offers a large surface to the air, by means of its branches, and the roots are still more closely in contact with the moist earth, while the whole plant is filled with fluids which conduct electricity and are decomposed by currents. Such being the case it can hardly be otherwise than that the electrical tensions between the atmosphere and the earth become equalised through the plant itself. Whether this acts favourably on the processes of vegetation, however, has not been scientifically investigated, since what has been done here and there in the way of experiments in this sense can scarcely lay claim to serious notice."

ELECTRICAL CONNECTIONS OF THE VEGETABLE KINGDOM

ELECTRICAL CONNECTIONS OF THE VEGETABLE KINGDOM

A Study for the Younger Generation

THE aphorism "There is nothing new under the sun," may be trite but it is, nevertheless, particularly striking when we are confronted with the work of Nature. We are apt to plume ourselves upon our progress in Applied Science, but ninety per cent. of the things we have learned about in the last century or two have been in evidence since the recorded beginning of time, so that if there is cause for wonderment it is not at man's keenness of perception or fertility of invention but at the really extraordinary manner in which he has neglected to sit up and take notice.

Of this instances could be multiplied almost *ad infinitum* and irrespective of limitation as to the scientific field. Education consists, mainly, in looking at the things we are told to look at and seeing what our teachers know to be there. Beyond that there is nothing about which we need give ourselves any concern whatsoever. And, as a rule, we do not.

Think of the millions of people who have cut an Apple in section without taking any heed of its obvious electrical structure. I did it myself, on and off, for thirty years and should, no doubt, have continued to do it had not a child opened my eyes.

We were giving a juvenile party—at Christmas time—and one of the youngsters asked me if there was any electricity in fruit. With an idea of affording amusement we went into the laboratory, where I joined up an Orange, a Lemon, an Apple in the circuit of the galvanometer by means of steel needles, as electrodes, and some flexible wire. The deflections obtained were of course attributed by me to

weak galvanic currents set up by the needles in contact with the acid secretion of the fruit. Dr. Trowbridge, Dr. Radcliffe, and others had given this explanation of the phenomena and, like everybody else, I had accepted it for fact and, in all probability, should not have given the matter another thought had it not been for one thing—in making one of the contacts I obtained *a reversal of sign.*

Now, it is quite certain that if the deflections were due to currents set up by difference of polarity in the needles no reversal of sign could occur unless the connections were reversed—and they were not reversed. In that fortuitous way an investigation was initiated and valuable knowledge gained. Like many other discoveries it had its origin in pure accident. I just happened to sit up for a moment and take notice!

With this preamble we may pay a visit to the garden and see what further information we can obtain.

Repetition is apt to become wearisome but it is necessary to remind the reader that the air is the positive and the earth the negative terminal of Nature's electrical system.

Electrical circuits are of two kinds, *i.e.*, "earth return" and "metallic." In the former one pole of the battery at each end is connected with the earth; in the latter with a second wire. That, I take it, is understood.

In the natural circuit the negative terminal is necessarily "earthed" because it is the earth itself. To complete the circuit the plant or fruit must have access to the positive air. In trees and plants this is gained through the stomata of the leaves, while in fruits the flower end—whether the flower is decayed or not—is never quite closed.

In these days of electric lighting everyone is more or less conversant with the fact that there are several ways of connecting or joining up incandescent lamps. Those in common use are called respectively Series, Series-parallel, and Parallel.

Series is when the lamps are strung, so to speak, one after another upon the feed wire; Parallel is when a group of lamps takes the place of one, and Series-parallel a mixture of the two methods. In the arrangement of batteries,

Series is carbon to zinc throughout; Parallel is carbon to carbon and zinc to zinc; and Series-parallel partly carbon to zinc and partly carbon to carbon and zinc to zinc. The first increases the electromotive force without increasing the current quantity, the second increases the current without augmenting the electromotive force, while the third permits of an adjustment of both current and electromotive force to meet requirements.

Nature employs direct—not alternating—current and therefore the sectional area of the conductor must vary in proportion to the quantity of current to be supplied. I say "must" because resistance is in the inverse ratio to sectional area and the natural electromotive force is constant. If you require more water in a given time and the pressure cannot be altered you must have a larger pipe.

In the vegetable world all three methods are resorted to but the one most in vogue is the series-parallel.

As will be seen also in the Chapter upon Acorns the seeds of the Oak are always joined up in series. There are only a few of them upon each stalk so that the latter does not need to be very thick. The stalk is, of course, a continuation of the feed wire from the earth.

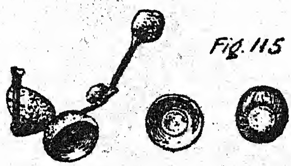


Fig. 115

The apex of the seed is left slightly open, in order that the circuit may be completed.

In practical electric lighting, as carried out in our houses, two wires are employed but for the reason above given Nature can dispense with one of them.

In the incandescent lampholder there are two contacts, to allow the current to enter at one end of the filament and pass out at the other. In the Acorn—while it is still attached to the tree—the apex is open, and two contacts at the base of the seed are not called for. But the two things are very much alike.

There are, as you know, several kinds of Ivy. Most, but not all, of the varieties have their leaves in Series. Figure 116 is one common to our gardens:

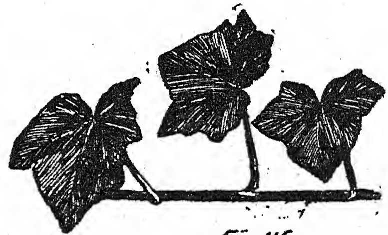


Fig. 116

IVY LEAVES—IN SERIES.

While the next is, I believe, an importation from Japan.

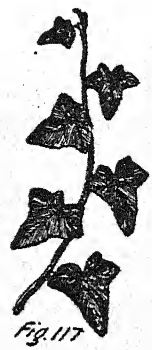
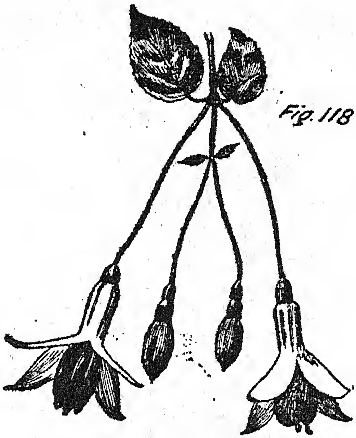


Fig. 117

IVY LEAVES—IN SERIES.

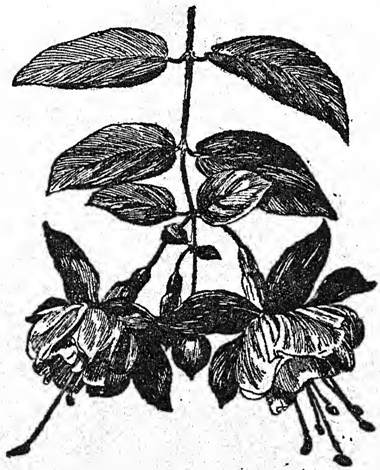
I daresay many other examples could be found, but the Series connection is comparatively rare. This may be owing to a greater quantity of current being necessary to the tree or plant than the Series method would allow. Series-parallel, on the other hand, offers facilities for adjustment and it is therefore, not surprising to find it largely exemplified in fruits, flowers, and leaves.

The next illustrations are of Fuchsias, the first an old favourite:



FUCHSIAS—IN SERIES-PARALLEL.

And the second a rather pretty group of Ballet Girls!



FUCHSIAS—IN SERIES-PARALLEL.

In both, the leaves as well as the flowers are in Series-parallel and this rule applies to every member of the Fuchsia family.

As regards the comparative thickness of the main leads of the Oak, the Ivy and our last two illustrations the respective sizes of the tree and plants must be taken into consideration. A fairer comparison would be with Cherry Apples.

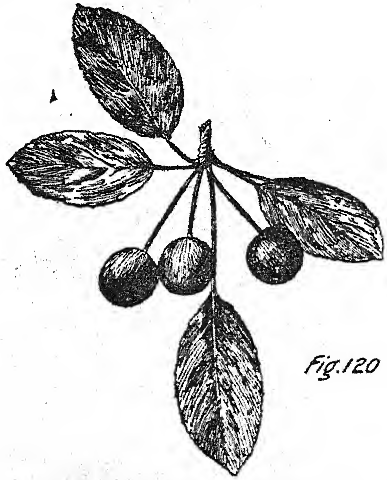
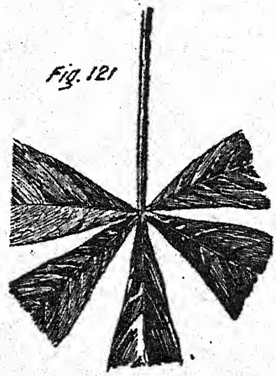


Fig. 120

CHERRY APPLES—IN PARALLEL.

And Horse Chestnut leaves, both of which are in Parallel.

Fig. 121



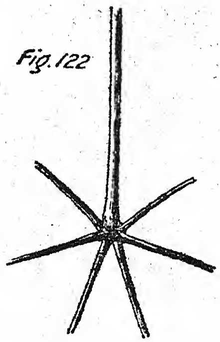
HORSE-CHESTNUT LEAVES—IN PARALLEL.

The thinner line in Figure 120 is a pin. Beneath it is the stalk upon which the leaves and fruit are borne, and it is certainly thicker than those of the Acorns and Ivies.

Nor can there be any doubt that the stalk of the Horse Chestnut is intended to carry a considerable quantity of current.

We can obtain a better view of it by stripping the leaves. They are, as will be seen, tapped off a central boss.

Fig. 122

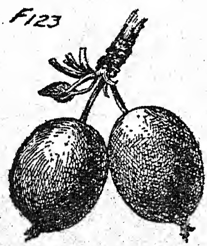


HORSE-CHESTNUT VENATION.

In Figure 121 there are only five leaves. Figure 122 has six and therefore the Stalk is a little thicker.

That, I think, should convince the reader, but in case it does not we will take some Apples from the tree. They are young yet but will serve our purpose.

F123

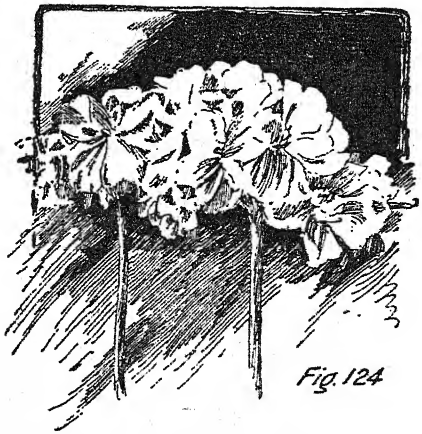


APPLES—IN PARALLEL.

I have cut off the leaves. There were eleven of them and the stalk is quite thick.

The flowers of the Geranium are in Parallel and if you look at them you will find that the diameter of the stalk increases with the number of flowers it has to support. In

Figure 124 the stem on the left bears five flowers and that on the right fourteen.

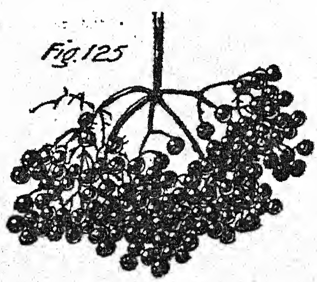


GERANIUM FLOWERS—IN PARALLEL.

Finally, and in order to clinch the matter, the reader may be referred to a bunch of Bananas. These are in Parallel and the stalk is of the proportions of an Atlantic cable!

And now let us hark back to Series-parallel.

In the cluster of Elderberries which forms the subject of our next illustration



ELDERBERRIES—IN SERIES PARALLEL.

it will be seen that there are five branch leads from the

feed wire and that from each of these a number of subsidiary leads ramify. Upon the latter the berries are carried *in Series*.

In a bunch of grapes a different arrangement obtains:

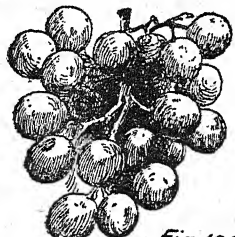


Fig. 126

GRAPES—SERIES-PARALLEL.

Here the main branch leads of the Elderberries are absent, but subsidiary leads are tapped off the stalk in such manner as to enforce symmetry of growth and upon these the Grapes are borne in Series-parallel. The bunches, however, are always in Series.

And so on, and so on. There is no dearth of material. Look round the garden and the orchard, at the Plums, the Cherries, the Raspberries, the Pears, the Peas and Beans:

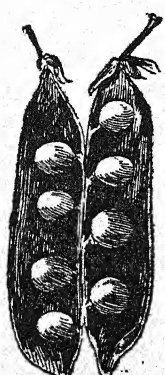


Fig. 127

PEAS—SERIES-PARALLEL.

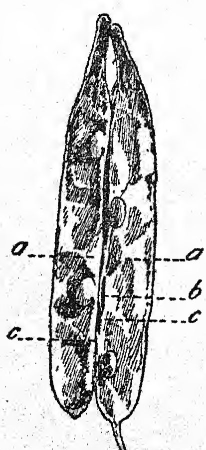


Fig. 128

RUNNER BEANS—SERIES-PARALLEL.

The feed wire in both splits at the shell end of the stalk into two and the Peas and Beans are carried alternately upon each. Notice particularly the leaves of vegetables, bearing in mind the fact that the greater number, especially in parallel, call for a thick conductor, or feed wire, to supply their needs.

Compare the sectional area of the stalks, having regard to the size of the plant, in all three modes of connection, and take a new interest in vegetable life; a phase of it upon which botany has, hitherto, been silent.

And now I am going to tell you something more. Every plant and fruit, flower and leaf of that plant, is a self-contained electrical cell, having positive and negative terminals like every other cell. They differ, however, from cells made by man in one important respect.

Two types of cells with which most people are familiar are the "Dry" and the "Leclanche." If these are kept in continuous use for an hour or so they become what is called "polarised," or in other words "used up." Not so with the vegetable cell. We will take two: an Apple and an Onion.

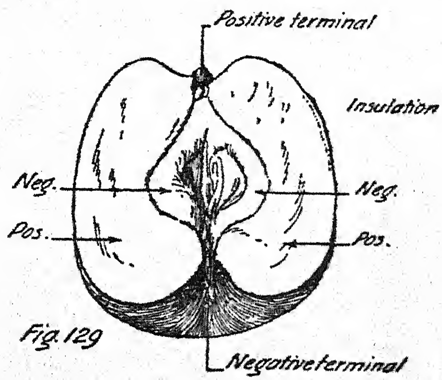


Fig. 129

APPLE—IN SECTION.

While the Apple remains upon the tree the stalk and core—which latter is insulated from the edible portion of the fruit—are negatively charged by the earth, while the flower end is open to the positive air. After it falls, or is

removed from the tree the end of the stalk is at once sealed, either by a resinous or gummy excretion or by becoming fibroid. The earth charge is cut off and therefore one would think electrification would cease. That is not so, however, The flower end is never closed and so long as it is exposed to air the core and stalk are negatively charged by induction ; the rind or peel conserving the energy of the cell.

You cannot polarise this piece of electrical apparatus, not even if you short-circuit it for six months on end.

The Onion is even more remarkable :

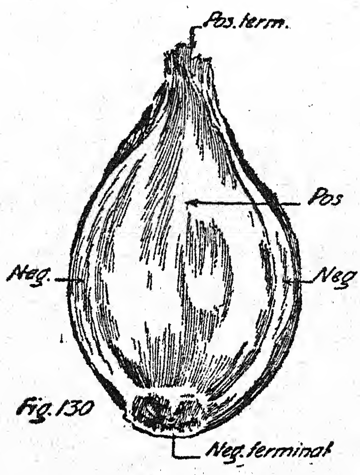


Fig. 130

Onion—in Section.

It is a standard cell of a very perfect description. The current evolved by it, in accordance with established laws, varies directly with size, but the electromotive force of them all is the same, *i.e.*, 0.086 volt. The outer insulation, consisting as it does of a number of dry, non-conducting layers, is very high and both negative and positive terminals are well defined, rendering it invaluable for all purposes where a standard cell of low electromotive force is required.

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